# PRODUCTION CONTROL

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BY

LAWRENCE L. BETHEL, Ph.D.(Ed.)
*President, Fashion Institute of Technology under the program of the state, University of New York, formerly Director, New Haven YMCA Junior College*

WALTER L. TANN
*Chief Production Engineer, Bureau of Ordnance, Navy Department*

FRANKLIN S. ATWATER
*Industrial Engineering Manager, The Fafnir Bearing Company Lecturer, Department of Business and Engineering Administration, Massachusetts Institute of Technology*

EDWARD E. RUNG
*Production Control Manager, United States Rubber Company, Footwear Division*

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PRODUCTION CONTROL



VI

# PREFACE TO THE SECOND EDITION

The power of American industry as demonstrated in the Second World War stands as a significant aspect of the history of that period. But this demonstration also marks a step in the development of American industry itself. It is inevitable that such a dynamic effort should lead toward permanent progress in manufacturing organization and procedures.

With this period of accelerated industrial development came a refinement of the techniques of production control and a recognition of its indispensable role as an aid to production. Industries were asked to make immediate and drastic adjustments in terms of products manufactured and increase in volume. This required major changes in plant facilities and personnel.

Those responsible for the administration of industrial organizations soon found that the changes in circumstances required changes in method. A demand arose for instructional assistance to personnel responsible for the control and coordination of the greatly expanded and diversified production activities. Out of this situation production control developed with a more clearly understood and more generally accepted functional place in the organization and management of the industrial enterprise. Since the war's end, shortages of material, difficulties of sales forecasts, disproportionate price rises, and other extreme uncertainties have continued its necessary advance in the industrial scheme

The concept currently prevailing in many manufacturing organizations and many collegiate programs of engineering and management accepts production control as part of an integrated series in which this control is based on such other controls as product design, methods, quality, and procurement.

Whereas the first edition of this text was developed in the early years of the Second World War for use in special classes for war production workers and in terms of the conception of production control at the beginning of that period, this second edition is an extensive revision in terms of (1) the current concept of production control in industrial organizations and (2) the needs of a collegiate program of management or engineering.

The focal emphasis throughout the text is on the specific functions in production control. However, in accordance with the current trend of interrelationship of controls, each of the other closely related controls is considered for clarity of interpretation.

This text has been written to follow or to supplement a basic course in industrial organization and management. It treats production control and the other closely related controls as specializations within the total field of industrial organization and management. Therefore, elementary or introductory phases, ordinarily learned through a course in industrial organization and management or through equivalent industrial experience, have been omitted.

The authors are grateful to Professor Erwin H. Schell, Chairman, Department of Business and Engineering Administration, Massachusetts Institute of Technology, for his suggestions relative to the general organization of the second edition. Acknowledgment is also made of the valuable contribution of John L. Schwab of the Methods Engineering Council in connection with Chap. XV on coordination; of the assistance of various members of faculties in institutions that are currently using this text in their classes; and of the effective assistance of Katharine Blenis Ramshaw, who made significant contributions to the editing of both the first and second editions.

THE AUTHORS

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# PREFACE TO THE FIRST EDITION

The national emergency that gained impetus in 1940 and 1941 placed its greatest demands on industrial production. It was declared that this country should become the arsenal of the democracies. Industries were asked to make immediate and drastic adjustments in terms of both products manufactured and increased volume. This required major changes in plant facilities and personnel. Industries, both large and small, found it necessary to make adjustments for the manufacture of products completely foreign to their usual line of production. Priorities, customers' quotas, and requests for indications of delivery dates many months in the future added to the general complexity of the situation.

Those responsible for the administration of industrial organizations soon found that the change in circumstances required changes in methods. A demand arose for instructional assistance for the personnel to control and coordinate the greatly expanded and diversified production activities.

The authors of this text participated in a survey of Connecticut industries in an attempt to outline the instructional needs and to organize material appropriate for serving these needs. Sixty representative companies were visited in the preliminary survey. Individual and group conferences were later conducted with representatives of 185 companies. The material presented in this book is based on the findings resulting from these contacts and from the previous industrial and teaching experience of the authors.

This book has been written primarily for the use of classes in production control organized under the Engineering, Science, and Management Defense Training Program. However, it should be of equal value to any course wherein the purpose, in whole or in part, is to develop an understanding and appreciation of the factors involved in the control of production. The authors have segregated this relatively small phase of the total field of industrial management in an attempt to make a more comprehensive presentation of instructional material that will appropriately serve industrial needs. They have sought only to present basic principles and to illustrate those principles through the citation of current industrial practice. The authors have

recognized that no system of control is fully applicable to varying types of industries manufacturing a large diversity of products or even to two companies manufacturing the same product. Any system of production control must be varied according to the general organization and procedures of a particular company. Throughout the book attention has been directed to the necessity for these variations. The application of principles to job-order production has been given particular attention in special sections of chapters.

Case problems are presented at the ends of chapters as an opportunity for the student to exercise methods of analysis and to make application of control principles. It is intended that the problems shall aid in stimulating thought and imagination within the student, which will, in turn, cause him to discover and analyze problems within the responsibilities of his own industrial employment and to construct appropriate procedures for handling them.

The material for the case problems has been taken directly from industrial experience. The authors are greatly indebted to the many production managers, superintendents, and engineers who have cooperated in the accumulation of this material as well as other examples and illustrations used throughout the book.

The authors wish to express special appreciation to the Chase Brass and Copper Company and the Farrel-Birmingham Company for permission to reproduce in the Appendix complete sets of standard record and report forms used in the control of production. These sets of forms are presented as an aid to the reader in understanding the continuity and functional relationship between forms when adapted to the use of a single industry.

Acknowledgment is also made of the courtesy of the United States Rubber Company, Footwear Division, in permitting the reproduction of sections of its manual "Written Standard Practice."

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THE AUTHORS

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# CONTENTS

# CHAPTER I

# THE CONCEPT OF CONTROL

**The Functions of Industry.** The work of the world is carried on by industries that may be broadly classified as follows:

1. The extractive industries, such as agriculture, animal breeding, forestry, and mining.
2. The manufacturing industries, which convert the products of the extractive industries into finished products, or into semifinished products that require further conversion or processing.
3. The generation and distribution of power.
4. The transportation industries.
5. The distribution and service industries.

As we are concerned with the manufacturing industries, a definition of the term *manufacturing* will be of use. By common acceptance, manufacturing is a series of steps in which material is given new form by predetermined intention, usually through the use of machines, tools, and labor.

The methods by which manufactured goods are produced are termed *production methods*, and the output of a manufacturing establishment is termed the *production* of that establishment.

**What Control Is and Does.** A general definition of the word *control* as given in a dictionary would be "to exercise a directing, restraining, or governing influence." Within the past few years the word has carried special meanings, chiefly in connection with governmental controls of sugar, rents, and building materials, and price controls on meats, groceries, and clothing, to name but a few. To many people the word has been synonymous with a scarcity of goods or services, thus accenting the "restraining" meaning.

However, the meaning of control as used in connection with management of industrial enterprises is more definitive. Here the word refers to the way in which an industrial enterprise is made to conform to satisfactory predetermined procedures and policies. Controls may be applied to administrative work, to finances, to sales and distribution, and to production. Thus defined, it is readily seen that controls do not necessarily "restrain," but rather direct and accelerate the procedures and processes of an industrial activity.

As we are concerned particularly with the control of production in manufacturing industries, we may define production control as the mental and physical techniques and procedures employed to the end that the right quantity and quality of a product shall be produced at the right time by the best and cheapest methods. Production control, when properly organized and functioning, acts as a preventive influence and not only as a "fire department" to put out a blaze of malfunctioning and inefficiency. A smoothly operating production-control department will foresee bottlenecks before they occur, will be aware of a coming shortage of materials, and will be able to take steps either to minimize the effect of these difficulties or to head them off.

The utilization of controls in the management of a business enterprise does not necessarily imply the need for a number of complicated printed forms with attendant clerical expense. For an elementary example of control, consider an office receiving a large volume of correspondence from dealers, customers, suppliers of raw materials, etc. If this mail is merely delivered to the desks of those persons responsible for replying to it, there will be no available record of its location should occasion arise necessitating its recovery for instant reference by other persons. Further, as a matter of policy many companies set a deadline date of a certain number of days from receipt of correspondence, within which time at least an acknowledgement of receipt must be made. To provide a *locator* of distributed correspondence a simple control is set up, carrying the name of the company or person writing the letter, the date of the letter, the subject, the department, the person whose responsibility it is to prepare a reply, and the deadline date when the reply is due to go out. When the reply is mailed, the incoming letter with a copy of the reply is returned to the main files and the control is so marked. This is a simple example of a control, but it embodies the same principles as does an elaborate production-control system in an automobile plant in providing a statement of things that should be done and, after their accomplishment, recording the fact that they have been done.

The mechanics and procedures of control may vary from a simple sheet as described above, which might be just a longhand-written sheet, up to the huge visual-control boards used in the largest manufacturing organizations. The principal forms of control are

1. *Printed forms*, or those produced by commercial reproduction processes such as mimeograph, ditto, or other means.

2. *Visible index* or card record systems, such as Kardex and Cardineer.

3. *Gantt-type charts*, which plot accomplishment against time and thus present a graphic record.

4. *Punch-card and tabulating equipment*, such as IBM and Remington-Rand.

5. *Visual-control boards*, which are a mechanization of Gantt-type charts. These may be elaborate and especially made boards designed for a given control task, or they may be commercially available boards, such as Productrol. These forms of control may be likened to the compass, radio direction finder, radar, and other navigation instruments on the bridge of a ship. They are aids, but require an experienced person to interpret the story they tell.

It is not our purpose to recommend any one of the above as the most desirable form of control mechanism, as that is always dependent on the requirements and characteristics of the job the control is expected to perform in a particular installation. However, it may be said that for an exposition of the status of the major elements in a control system, visual-control boards are in high favor. The story they have to tell the persons responsible for the operation and results of a department or plant is always visible at a glance. Further, they readily permit *control by exception*, *i.e.*, the item or shop order that is seriously behind schedule stands out like the proverbial sore thumb, and attention is automatically concentrated on this item. Usually the operating details are carried on record sheets, cards, or other forms, with the final results posted on the visual-control boards.

An easily understandable comparison would be the profit-and-loss statement of a business, behind which are thousands of time cards, sales slips, order forms, purchase orders, etc. For this reason visual-control boards achieved great popularity during the Second World War, when this nation was making a herculean effort to produce munitions for the fighting fronts at unheard-of rates of production, together with goods necessary to the civilian economy. An inspection of a visual-control board does not always reveal good news, because it shows up the bottlenecks, but it presents a record of conditions as they are, acting as a spur to improve or remove the unfavorable factors.

**Necessity for Controls.** When industry was small, with relatively few people employed, the owner was usually the operator and there was no need for such controls as are required today. The owner could carry the few details either in his head or in a memorandum book. But today, with the prodigious growth of industry, such an accomplishment would be impossible.

**The Growth of Industry.** Surrounded as we are by the comforts of modern living, made possible by the phenomenal growth of industry and the consistently increasing adaptations of science to the aid and comfort of man, we seldom give thought to the rate at which industry has grown over a comparatively short span of years. And yet it is industry that has made possible this standard of living to which we have become accustomed, and that furnishes a livelihood to the millions who are engaged in its various phases.

The U.S. Bureau of the Census furnishes some statistics that show the rapid growth of manufacturing for the period extending from 1849 to 1939. These statistics show that in 1849, when the United States had a population of 23,191,876 (1850 census), there were 123,025 manufacturing establishments of all kinds, employing 957,059 wage earners, whereas fifty years later, in 1899, when the population was 75,994,575 (1900 census), there were 207,514 manufacturing establishments employing 4,712,763 wage earners. How rapid was the acceleration from the turn of the century up to 1939 and how apparent was the era of the large unit are shown by the fact that for that year the Bureau of the Census records a total of 184,230 manufacturing establishments, but with 7,886,567 wage earners from a total population of 131,669,275 (1940 census).

In 1850, the population of the country was 87 per cent rural, whereas in 1940, according to the census, the rural population was about 44 per cent of the total. This change coincides with the increase in the number of wage earners in industrial establishments, which are located for the most part in cities. Yet so far-reaching are the effects of the industrial advances that we find the farmer, except in remote regions, dependent in many ways on the products and movements of our industrial society. His basic work of tilling the soil is mechanized by tractors; he uses motor trucks to get his products to market, traveling over roads made necessary and possible by the automobile. No longer is he the "outlander," and the radio, motor transportation, and modern housing conveniences often make him the envy of his city brethren.

Each new basic discovery and application of the forces of nature for the benefit of man have brought into being new industries. Ready acceptance of the products of these industries by the buying public has caused demands for goods that have led to the formation of industrial producing units employing in the neighborhood of 80,000 men, as at the River Rouge Plant of the Ford Motor Company. Specialization in product has led to specialization in the component opera-

tions that are employed in the manufacture of the product, and this in turn, naturally, has led to the division of labor to a degree not visualized fifty years ago.

**Division of Labor.** In the days of the nineteenth century, the average manufacturing plant was small and was staffed with mechanics and artisans who were masters of every phase of the work required for the manufacture of the product. The area occupied by the plant was generally small, and all operations were visible to all workmen. Those were the days of easy contact between the owner and the workman. The owner was often the superintendent or manager. The workman not only had the opportunity to observe and learn the processes used in the manufacture of the product but also had the chance to know something of the uses to which it was put by the buyer and of the weaknesses of the product when in use.

In the metalworking industries of those days, a machinist would perform all operations on a shaft, let us say, whereas today the various operations are performed by as many machine operators as there are operations, each operation being performed on a machine used only for that purpose.

This division of labor naturally introduces complications in the endeavor to follow the progress of the work. Under the old system the all-round machinist would cut off the stock, rough-turn to size, perform the boring and facing operations if required, cut the threads if any were required, and mill the keyway, drill and tap any required holes, and finish the operation by grinding any areas that required such a finish.

But with the advent of metalworking machinery for special purposes and the specialization of operators to man these machines, in addition to the increased demand for production due to the highly mechanized character of modern life, we should find it extremely difficult, if not impossible, to follow the progress of parts through the plant unless we were aided by some sort of a progress and record system. We should need a system that would show us the amount of work ahead, the progress of operations on each part, and the location of the part at any particular time. It should also furnish us with an over-all view of the status and location of all parts that comprise the job or order, so that they will reach either finished stock or final assembly in time for completion on the desired date.

Under the old small-shop system, the all-round machinist had the part under his control at all times; he was the only man working on it. Today his successor, now specializing on the operation of a cutoff saw,

cuts off the material from bar stock, in accordance with the number of parts specified on the job ticket, and the move man comes with his truck and takes them to the next operation. Industry has grown so large and impersonal that the cutoff-saw operator may not even know the location of the next operation. He just proceeds to cut off the material for his next job ticket, the material having been brought to him by move men, who withdraw it from the stock racks in accordance with the instructions on their job ticket. Thus it is readily apparent that with parts located throughout the plant in various stages of completion, it is imperative that their movements from operation to operation be recorded and that the completion of each operation be likewise known, so that the availability of men and machines for the next operation may be properly planned. Otherwise confusion would reign, it would be impossible to keep men and machines steadily employed, and a specific customer's order would be shipped only after other orders had been sidetracked in order to give his the right of way.

**The Transfer of Skill.** Another extremely important principle underlying the rise and tremendous growth of the manufacturing industries is the transfer of skill from the worker to the machine. Reduced to its simplest terms, this means the ability of modern science and engineering to develop and produce machines and tools that either automatically or semiautomatically, under the guidance of an operator, perform operations or processes in a manner equal or superior to like operations or processes performed by a skilled workman. This principle of the transfer of skill is one of the basic causes of the growth of the manufacturing industries. It has been the fundamental basis of modern interchangeable manufacturing, which is sometimes known as *mass production,* meaning, in a popular sense, the production of masses or quantities.

Thus we see the relationship existing between the transfer of skill and modern manufacturing, for the application of this principle makes possible the utilization of the services of semiskilled or unskilled operators for the production of large quantities of goods. Under the old handicraft system and the days of the now rapidly disappearing all-round mechanic, "manufacturing" in the accepted sense of the word was unknown, and all industry was dependent on the craftsmen and the apprentices.

Modern mass-production methods and interchangeable manufacturing are responsible for our present standard of living, and complementary to this we also find our accepted standard of living responsible for and a spur to further developments tending toward "more goods

for more people at less cost." As production rates rise, means for control and coordination of production processes within a plant become not only desirable but absolutely necessary. The control of production within a plant employing 25 men presents few difficulties, but the control of production within a plant employing 2,500 workmen is a problem of no mean proportions. When we go into extremely large units, such as General Electric at Schenectady or Ford Motor Company at River Rouge, we find control and coordination systems that represent some of the best thought of present-day industrial management.

**Specialization.** In addition to the foregoing developments of the division of labor and transfer of skill, another factor displays tendencies similar to those mentioned—specialization. The meaning in this instance is that manufacturing establishments concentrate their efforts on certain phases of the industrial field and on one or related lines of the product. During the last half of the nineteenth century, for example, it was common practice for a shipyard to construct not only the hull but the engines and boilers of a ship as well. Today most shipyards subcontract the boilers, engines or turbines, and reduction gearing to specialists. This is partly due to the increased mechanization and electrification of all phases of shipbuilding but in the main is a result of the trend toward specialization.

Specialization in any particular field of industry naturally tends toward greater volume of production of the specialty on which the plant is engaged, and the plant is therefore faced with the necessity of utilizing the principles of *division of labor* and *transfer of skill* described in the foregoing paragraphs.

**Standardization.** As *specialization* is the confining of effort to a limited field, *standardization* is the reduction of a specialized line or lines of production to the least possible number of models, types or sizes. Models or styles are often dictated by public demand, and, in fact, new styles must often be designed and produced to create demand by the buying public for something new and thus bolster sales and production. This is true of consumer goods, from major purchases such as passenger automobiles down to large-volume-production items such as radios, clothing, food specialties—even cigarettes.

Capital goods, such as ships, locomotives, motor trucks, heavy machinery, and machine tools, are usually not subject to the fluctuations of fashion, but technical developments and improvements may make existing models too expensive to operate. Yet there are some instances within the past few years in which railroads, for example,

have had designed and constructed high-speed trains drawn by Diesel electric locomotives, with the primary purpose of attracting new passenger business, when they could have continued to use existing steam locomotives and standard-design cars.

New improvements in machine tools that will greatly increase production and lower costs find ready markets, especially with manufacturers of consumer goods, as competition demands that costs be cut wherever possible if sales are to be maintained or increased. Cases could also be cited in which ships have been replaced by new ships incorporating new-design propelling machinery, cargo-handling equipment, etc., because these advances made it economically unsound to continue the operation of the older vessels with their higher fuel and operating charges.

Standardization then becomes a problem of time—that which is standard today may be obsolete tomorrow.

The manufacture of several current models, types, or sizes at one time in a manufacturing plant presents several problems in the control of production that obviously are not present when only one standardized product is made. Nevertheless, with the one standardized product, manufactured at a high rate of production, means must be developed and utilized for controlling the production of the component parts and their readiness for assembly, completion, and shipment. The necessity for control of production increases in proportion to the variety of products, the number of sizes or styles of each kind, and the volume of production and size of plant or plants.

**Assembly.** If there are assembly operations to be performed after the component parts are made, it is essential that the parts reach the assembly department in the correct order for their use and also that they be of the desired quality. Great loss in time, money, labor, and customer good will will be suffered unless means are taken to ensure this. If a satisfactory flow of parts is not maintained, assembly work can be but partially completed, which results in inability to meet promised delivery schedules and an increase in semifinished-goods inventory, with a consequent addition to the financial burden. Workmen, because of reduction in earnings, may become justly disgruntled. The delay may result in cancellation of the order by the customer or, at best, may cause dissatisfaction.

Clearly, then, any procedure or method that can keep materials moving from their raw to their finished states is not only worth while but necessary.

**Mass Production.** The mass production of automobiles, radios, refrigerators, electrical appliances, and numerous other commonly accepted articles is made possible only by the adoption and full utilization of the best known methods of production control.

Automobile production methods are a good example of the necessity for absolute control of production. One of the popular "all-three" cars can be produced at the rate of 2,000 cars per day, or three per minute. Each car is composed of about 15,000 pieces, which in turn are assembled into hundreds of units from which a car is built. Here we find about a dozen body types and an almost infinite variation in color combinations. Yet production control enables the right body to be ready at the right time for assembly to the right chassis. In one plant, only one error in this respect occurred over a period of ten years of operation.

Such a project as the foregoing calls for planning of each minute detail, from the time the "go-ahead" is given for ordering raw materials for the next year's models until the last car of that year has been driven off the assembly line.

The same is true of other phases of mass-production manufacturing, such as radios and other products previously mentioned. Airplanes, up to the present, have been built on a lot-manufacture basis but are now being manufactured on a mass-production basis, in so far as their complicated construction will permit.

In mass-production plants, the production-control department is one of the most important divisions of the plant. An error in the department can result in the temporary closing of the whole plant. It is safe to say that without production control there could be no mass production, and since this is but another way of saying that there could be no automobiles within the reach of lower incomes and no radio in the wage earner's home, it is easy to see the economic and social implications of the control of industrial production.

**Job-order Production.** Although the products of the highly organized, semicontinuous-process industries, such as the automobile, radio, refrigerator, shoe, and textile industries, offer the most obvious examples of the efficiency of modern manufacturing methods, there is another classification of manufacturing, less apparent to the general public, that is nevertheless the cornerstone on which most consumer-goods industries are built.

We refer to the capital-goods industries, in which are included, for example, the manufacture of machinery, locomotives, steamships, and

commercial aircraft. An example of a *capital-goods* as distinguished from a *consumer-goods* industry would be a rubber mill, processing rubber in the plant of a tire manufacturer. The manufacture of the rubber mill is a function of the capital-goods industry; the automobile tire processed in that rubber mill is a form of consumer goods.

Capital goods usually have long lives. Since they are the equipment on which consumer goods are manufactured or transported, the demand for them is capable of wide fluctuation. For example, in 1932, a depression year, the demand for capital goods was only 27 per cent of the 1929 figure, whereas the demand for the necessities of life, as represented by consumer goods such as food and textiles, did not drop at any time during the depression below 75 per cent of the 1929 demand.

Thus it will be seen that for this reason alone it is impossible to build capital goods for stock. We must also remember that each purchaser of capital goods is making a large investment. He usually has his own ideas and specifications regarding the design and construction of the equipment he is purchasing. Hence it follows that each order must be handled as a special order or, as it is termed, *job-order production.*

In job-order production, products are made to customers' orders *only.* Repeat orders are unusual, often each order differing to a greater or lesser degree from any order previously produced. Usually there are no assembly lines and no conveyors, since the size of parts alone would prohibit such equipment. Each order is handled individually and constitutes a separate problem in routing the necessary operations to the proper machines and the movement of semifinished parts to subsequent operations.

In one large plant engaged in job-order production there are often upward of 500 orders in various stages of completion passing through the plant, with perhaps no more than 10 out of the 500 related or similar in any way. About all that they have in common is the fact that they are complete machines or repair parts for machines and that they are made of iron, steel, brass, or aluminum.

One does not need to be an experienced production man to discern the necessity for a definite means of controlling every movement in production, from the procurement of the raw material to the shipment of the completed order. The control of job-order production requires a more intimate knowledge of the plant, the personnel, and the various products than any other branch of industry. This is especially true

in job-order production plants of large size. Despite the tendencies toward specialization that have been previously discussed, there are today, and doubtless always will be, manufacturing plants devoting their efforts to a long list of products or equipment made only to a customer's order.

**Coordination of Departments.** The maintenance of continuous movement of production through the various processes in a modern manufacturing plant requires the coordinated efforts of all departments concerned. Material must be purchased, received, checked, and entered in the records. Primary operations must be planned and performed. Semifinished parts must be moved to subsequent operations; and finally, the various component parts must arrive at the assembly department in their proper sequence for building the assembly or finished product.

This requires the concerted efforts of sales, engineering, purchasing, manufacturing, and transportation departments and further requires that the work of all these departments be tied in together in such a way that the various steps in filling an order will proceed at a scheduled rate, with the smallest possible investment in work in process. For example, overbuying of raw material in excess of requirements will not only tie up funds for a considerable period but will present a problem in raw-material storage.

Again, if the industry is of the continuous-process type, manufacture at a rate in excess of market demand may tie up funds in finished products to an extent that may seriously restrict the availability of working capital.

But the reverse of these circumstances may also present difficulties. For example, failure of the sales department to forecast demand properly may result in the failure of the purchasing department to procure sufficient material to supply the demands of a rising market. This may mean a loss of sales.

Usually the most efficient agency to coordinate and consolidate the efforts of all departments of a manufacturing plant is the planning and control department or the production-control department. Regardless of its name, this department can effectively initiate and follow the handling of each order from receipt to shipment. This is especially necessary in job-order production industries because of the variations in product, processes, and general requirements. Here, too, is found a departmental activity—engineering—that usually does not require much attention in a plant devoted to continuous process or mass production.

Since every order received in a job-order plant requires engineering, sometimes in the simple form of specifications only, we thus find this additional phase that must be expedited before the actual manufacturing processes are under way in the plant.

Often a manufacturing organization will be composed of two or more plants, sometimes separated by hundreds of miles. Because of the characteristics of the company's products, one plant may contribute raw material, semifinished parts, or finished assemblies to one or more other plants of the company. Coordination of the manufacturing efforts of these separate plants is absolutely essential if manufacturing schedules are to be maintained and work-in-process inventories kept at a minimum. A central planning and control organization is usually maintained, with a local organization at each plant. Constant interchange of information is necessary. Important decisions must sometimes be made quickly if the combined production of widely separated plants is to be maintained and the greatest economic use made of such extended plant facilities. Without both centralized and local control of production, the coordinated operation of such an industrial organization would be impossible.

**Human Problems Involved.** Although modern manufacturing methods are responsible for the high standard of living and the tremendous increase in national wealth, they have also created some problems in human relations. The advent of the factory system, which occurred at about the middle of the past century, closed the door of opportunity for individual ownership to the great majority of industrial workers. Their craftmanship was forced to give way to modern machine methods, and the investment necessary in machinery to equip a manufacturing plant was so large that rarely could an individual workman, or even a group of workmen, raise enough capital to finance his own business.

Hence labor became dependent on capital and completely separated from ownership of the tools of production. Furthermore, as the refinement of manufacturing methods increased, the satisfaction of participation in constructive work decreased because of the extreme division of labor and specialization made advisable through improved methods. Workmen performed but one task or made but one part. Plants became so large and departments so separated that often the workman had no chance to see what ultimate use was made of the part produced by his machine.

It seems only natural, therefore, that the workman, through no fault of his own, should lose some of the interest engendered by close

contact with the entire plant, such as was enjoyed by his predecessors of an earlier day and of the small shop. In an effort to increase his interest, management has introduced incentive systems based on the principle that increased production warrants increased earnings for the workman.

Without a means for the control of production, there would be no means available for the determination of incentive earnings. Furthermore, without means for production control there would be no method of ensuring a continuous flow of work to the various machines and processes—an essential if the workman is to avail himself of the added earnings made possible by the incentive system. Material must be received in proper quantities at the proper time; semifinished parts must be moved to the next operations; finished parts must be moved to the stock room or assembly, etc. Production control makes this possible, and in that way it makes possible at least a partial solution of the problems presented by the modern industrial system.

# CHAPTER II

# ORGANIZATION FOR CONTROL

Picture yourself driving a car along a suburban highway. Your attention is concentrated on cars coming out of intersections, pedestrians crossing the road, and traffic lights momentarily threatening to turn red. Your speed is normal for the driving conditions encountered; you are making reasonably good time.

Suddenly your car engine starts to sputter and cough. Now your attention is diverted from the traffic to your car. You slow down; you look for a revealing story in the instruments in front of you. The sputtering gets worse. You pull over to the side of the road and stop.

What's wrong? Several possibilities enter your head. Could it be that you are out of gas? Has dirt in the gas found its way into the fuel system? Is the fuel pump not working properly? Of course there are other potential sources of your difficulty, but let's limit our discussion to these three possibilities.

If you are out of gas, there is but one solution. You fuss around in the rear of your car, come out with a can, and hike back to the nearest gas station after enough gas to get you started.

Suppose, on the other hand, there is dirt in the fuel system. You may decide to drain the carburetor and blow out the fuel line, or you can try to limp along to a garage where the situation can be remedied. In any event you will undoubtedly want to talk with the service-station manager from whom you buy your gas, and perhaps you will go so far as to change your source of supply.

Finally, if it should develop that a faulty fuel pump is the cause of your trouble, very likely you will have to stop and have it repaired or replaced before you can continue on your way.

Now picture yourself in industry as a production manager steering your manufacturing unit down the highway of production. Your attention is concentrated on the normal everyday problems: the little bottlenecks that crop up, the shifting of production employees for balanced flow, the decisions that make for a steady rate of production.

Suddenly your manufacturing unit starts to sputter and cough, and it loses momentum. You look around for the cause of the trouble.

Perhaps you have used up your bank of raw materials—in effect, you're out of gas. You look at the inventory-control records (your gas gage) to see why you didn't have a warning of the dwindling supply. Perhaps your control system was not operating properly—a control failure. Possibly your control personnel failed to call attention to the potential material shortage or failed to initiate a replacement order at the proper time—a human failure. In any event you will want to take steps to correct whichever kind of failure did occur. But of course your first move will be to procure more gas to get the unit in operation again. You hike to the office of the purchasing agent who is responsible for obtaining and keeping you supplied with the gas you need and discuss the problem with him.

Suppose, instead, that the trouble with the performance of your manufacturing unit arises out of poor-quality material—dirt in the fuel system—that engenders technical difficulties in the production process. Now you as production manager confer with the man in charge of quality control. Must production be stopped altogether until the dirt is removed? Can the plant limp along at reduced rate of flow until the situation is corrected? Decisions on such problems as these must be made. If a vendor has supplied off-color material, here again a conference with the purchasing agent is in order, and a decision may be made to change the source of supply.

Lastly, suppose your difficulty arises out of a breakdown of a vital tooling element—the fuel pump. Then the production manager may have any one of several people to see. If the design or construction of the tooling was at fault, the chief of the tooling section will be involved. If the failure resulted from operating the equipment at too great a rate of production, the man in charge of standards will be concerned. If maintenance was improper, the key man responsible will probably be called in.

This analogy could be carried forward almost indefinitely, but by this time its purpose—to show the relationship of production control to the rest of the plant organization—should be fairly evident. Production control in its broadest sense is a part of an integrated series of controls. As the right arm of top management in a plant, it serves as a bridge facilitating the passage of production: the manufacture of goods. Just as any bridge must be supported on a foundation, so the production-control bridge relies for support on other controls. While the number and nature of these allied controls vary according to the type of enterprise and processes involved, there are nine fairly universal controls that in most plants are piers for the production-control

bridge (see Fig. 1). If any one pier—or, in fact, any single stone in a pier—fails to carry its share of the load, the bridge is correspondingly weak. If any stone fails completely under stress, the bridge collapses and the effectiveness of the manufacturing unit, a highly tuned mechanism in its own right, is damaged or destroyed in the crash.

For instance, where the product is not designed for ease of reproduction, where the process is not established for maximum productive efficiency, or where the facilities of the plant, financial as well as productive, are not budgeted for proper balance—these are the weak foundation stones that are certain to impede the progress of production. So also will production difficulties occur if inventories are not replenished properly, if quality of material or parts is not maintained. or if cost information is not applied to control plant operating expenses. After all, how can production control be effective if the enterprise has not first solved its other control problems?[1] Only through a sound, active set of controls can the desired coordination of men, machines, materials, and money be attained under the guidance of that fifth "m"—management.

It may be noted in passing that a dip or crack in the production-control roadway very often serves as a warning that one of the sup-

[1] As a case example revealing the importance of effective controls, the following experience of the Hamilton Watch Company is cited from *Fortune*, January, 1947, pp. 100 *ff*.: "Prior to 1927 the making of a new model [watch] had all the attributes usually associated with the handling of a temperamental artist. The master watchmaker withdrew into his eyrie and after as much as two years of labor emerged with the first specimen. This was disassembled and its parts delivered to the respective department foremen. From this point until final assembly, the manufacture of parts was entirely the province of the individual foreman or job boss. He arranged for labor and materials, delivery of tools and dies depending on his personal relations with the machine-shop foremen. What drawings existed were post-card size. Quality and experience were stored within the foreman's skull or in the pages of the little black notebook that each one carried. Under these conditions a watch obviously could be made—but not very efficiently. Since standards of tolerance were lax, it was not surprising that, say, pinions turned out two thousandths of an inch too large. Assembly required the talents of a master craftsman, one who could match an outsize pinion with an extra-large jewel by feel.

"On taking charge [in 1927, the new vice-president in charge of manufacturing] ordered a reduction to detailed blueprints of technical data heretofore known only to foremen. The project took years and the utmost in diplomacy, but it paid off. It enabled engineering management for the first time to survey and thus control every step in production. Tolerances were established and rigidly enforced. Inventories were brought into line. Final assembly—up to insertion of the balance wheel—became a routine job. A personnel department was set up. Formalized, on-the-job training courses were established. The net result was more flexible control from the top—and an improved product requiring 30 per cent fewer man-hours to make."

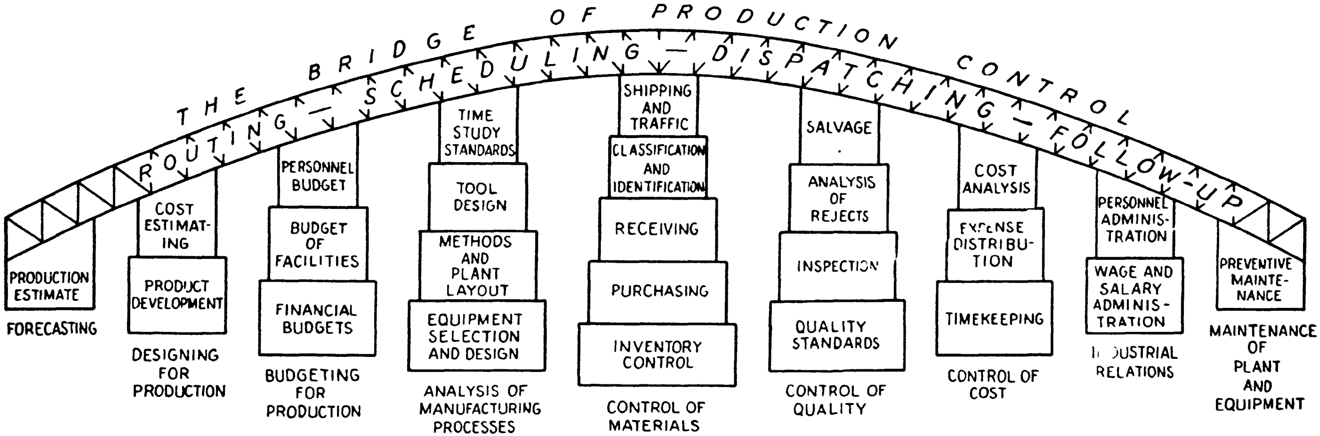



FIG. 1. Nine typical controls that pier the production-control bridge. It is important to note, however, that not all of these controls may be found in any one company, and others not shown here may be necessary for certain types of enterprises. Also, the grouping and placement of controls within the plant organization will vary from company to company.

porting controls has weakened and is not carrying its portion of the load. In this respect the production-control function acts in a preventive capacity. It can warn of impending failure in time for remedial action to be taken.

The close, integrated relationship of production control and allied controls will be developed further in this and in subsequent chapters. However, it may be well to note here that two piers of the production-control bridge—namely, the administration of personnel and the maintenance of plant and equipment—are deemed to be beyond the scope of this book. The reader is thus referred to books on industrial organization and management that cover these topics.

**Production Control in the Plant Organization.** It has been said: Line men in an organization make products, staff men make progress. If we accept this statement as a truism, production control must logically be a staff unit, or more strictly, a functionalized-staff unit.[1] Production control serves the manufacturing division and consequently comes under the authority of the top-line manufacturing executive, usually the works manager (see Fig. 2).

Within itself the production-control department has a line-organization structure. The man in charge of the department is usually called the *production manager.* He should have complete control over the quantity of goods produced by the manufacturing unit. He is the one who says how much of what is to be produced, and when. Under his direction the influx of sales orders or the sales forecasts are boiled down into production schedules or orders, at a rate and in a sequence to produce a minimum of internal disorders in the plant. Any change in production requirements produces some indigestion within the plant. However, a good production-control department so feeds its plants that the manufacturing unit can operate without suffering the extremes of hunger pains or of constipation.

While the production manager *is not responsible* for control failures outside the scope of his department, he *is vitally concerned* with such failures. They can seriously disrupt the planning of his department

[1] The authors of this volume differentiate between staff and functionalized staff as follows: Staff men can give advice only within the confines of their field of endeavor. They cannot make decisions or be charged with the execution of decisions, for these rest squarely with the line organization to which staff men offer their advice. Functionalized-staff men, on the other hand, have the authority to make decisions and give orders to carry out these decisions, but again only within the area of delegated functional authority. For a more detailed explanation of the operation of functionalized-staff units, reference to standard texts on industrial-management is suggested.

and likewise its effectiveness. Therefore the production manager's attention or that of his department should be turned toward the causes of each failure to the end that the trouble will not be repeated. For example, if the toolroom becomes bogged down with work and the tooling for a new job is not available as required, the production manager, while not responsible (assuming that authorization to place tool orders for the job was issued sufficiently far in advance), is vitally concerned and will very likely initiate an investigation to determine whether additional toolroom personnel, extra hours of work, further

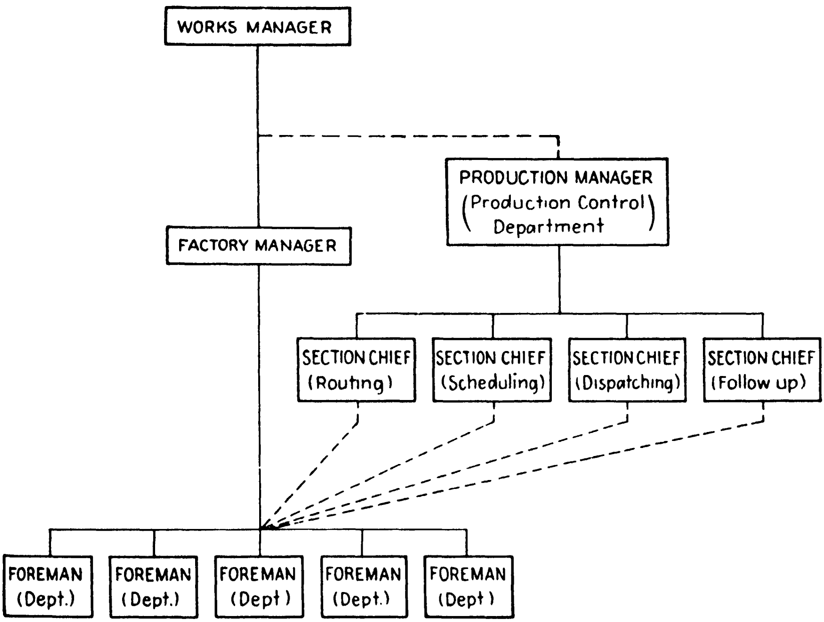



FIG 2. Typical organization of a production-control department. Solid lines indicate line-organization relationships. Dotted lines indicate functionalized-staff relationships.

equipment, or more subcontracting will best solve the problem. Then he will see to it that the necessary steps are taken.

Furthermore, the production controls frequently will signal the imminence of some other control failure in time to prevent its occurrence. Perhaps the bank of material between two operations is becoming dangerously low. This fact will quickly register on the production records and indicate the need for investigation. Possibly the personnel department is falling down on its assignment to hire and train employees for the preceding operation. Or again, it may be that equipment for the preceding operation is so much in need of

maintenance that it is not producing properly. Still another root of the trouble might be an excessive rate of rejections of the item at an earlier operation. In any event, the production-control record sounds the alarm, and the people concerned can organize to catch the burglar before he can carry out his depredation.

**Organization of the Production-control Department.** The internal structure of a production-control department, while it varies from plant to plant, generally embraces four functions: routing, scheduling, dispatching, and follow-up.

*Routing* determines *what* work shall be done on a product or the parts making up that product and also decides *where* and *how* the work shall be done. Thus it establishes the operations in the process, the sequence of these operations, and the class of machines or personnel to be utilized. *Scheduling* is the procedure whereby the priority of the work is established for the plant. It concerns itself with *when* work is to be performed. *Dispatching* covers the assignment of work to departments, machines, or operators in the sequence determined by scheduling. Thus, in effect, it determines *who* shall perform the work. *Follow-up* is a coordinating function which checks performance against the plan, then searches out and endeavors to correct conditions that interfere with proper performance.

Generally, if the size of the plant warrants, the production-control division is subdivided into four sections, each covering one of the aforenamed functions. Each section operates under a section chief who in turn reports to the production manager.

**Allied Contrcls in the Plant Organization.** To round out the plant organization for control of manufacturing, we should consider briefly the position of the allied controls in the organization structure. In this connection it will soon become apparent that there is an endless number of variations as far as the positioning of these allied controls within the organization is concerned. Let it be remembered that a plant organization is a dynamic entity which must be tailored to fit the enterprise, its processes, and the capabilities of its key people. That no two plants have a comparable structure, or that the structure in the same plant changes from time to time, is quite to be accepted.

The allied controls and their position within the organization follow:

*Production Forecasting and Budgeting.* Functions performed by formal or informal committees composed usually of sales, financial, production, and engineering executives.

*Designing for Production.* Performed by a functionalized-staff department under the guidance of the engineering manager. Depending upon the importance of engineering in the company structure, the engineering manager may be in charge of one of the major divisions of the company and on an equal plane with the works manager, or he may be subordinated to the works manager and on an equal plane with the production manager.

*Analysis of Manufacturing Processes.* This likewise is a functionalized-staff activity performed under the direction of the engineering manager or by an entirely separate department which reports to the works manager.

*Control of Materials.* The control of materials is a functionalized-staff activity the external phases of which may be under the purchasing agent, with the internal phases under the production manager. Thus purchasing, receiving, shipping, and traffic may report to the purchasing agent, and the production manager will then handle the control of raw, in-process, and finished inventories as well as the classification and identification of materials.

*Control of Quality.* A functionalized-staff agency that operates under the manager of quality control, or chief inspector as he sometimes is called, who in turn reports to the top manufacturing executive, usually the works manager. Frequently the setting of quality standards, a legislative function, is divorced from inspection, a law enforcement function, and placed under the engineering division or department.

*Control of Cost.* A functionalized-staff activity carried on either by a department that reports to the works manager or by a department that reports to the chief fiscal officer: the controller or treasurer.

*Administration of Personnel.* A functionalized-staff activity in charge of the personnel manager, who is generally on an equal plane with the production manager and reports to the works manager.

*Maintenance of Plant and Equipment.* Still another functionalized-staff agency, the head of which generally reports to the plant's chief operating executive, usually called the factory manager.

**What "Control" Means to the Plant Organization.** No chapter on organization for the control of manufacturing would be complete without at least a few words on how the various control functions serve the plant operating organization.

A good way to test the effectiveness of the plant controls is to discuss them with the line supervision in the plant. If at once you start to lose friends and alienate people, the controls are not doing the kind of a job they should. If, on the other hand, line supervisors warm

up to the subject and recognize that controls simply make their job easier, you need have no worries on this score.

All control must be preceded by planning. In any control activity it is important to anticipate and prevent manufacturing difficulties before they occur. If, instead of concentrating on fire prevention, you wait until the blaze starts, you may find yourself with a conflagration on your hands—something that takes a large and well-equipped fire department to extinguish, and then probably not before the structure is severely damaged or completely destroyed. Planning usually can prevent the difficulties that arise when the control is "after the fact." To accomplish this planning, key control personnel must have the necessary time to think in terms of the future, to plan and develop new ideas, and to anticipate the needs of next week, next month, and next year. They simply cannot afford to spend all of their time on the problems and needs of the current moment.

### CASE 1

Referring to the bridge of production control (see Fig. 1), make an organization chart showing all the control functions in what you believe to be their proper position for a typical enterprise. For organization-chart procedure, see standard texts on industrial organization and management.

### CASE 2

*Whirring Propellers Company.*[1] The organization chart of the Whirring Propellers Company shows five major divisions reporting to a general manager. These divisions with their departmental coverage are as follows:

1. Engineering.
    - Product design.
    - Experimental shop.
    - Inspection.
    - Metallurgy.
2. Manufacturing.
    - Manufacturing departments.
    - Plant and Equipment maintenance
    - Tools engineering.
    - Materials control.
    - Personnel.
    - Purchasing.

[1] Fictitious name of an actual company.

3. Sales.

    Sales force.
    Advertising.
    Customer relations.
    Spare parts.

4. Service.

    Field service.
    Repairs.

5. Accounting.

    Pay roll and cost accounting.
    Finance.

### Preparatory Question

Comment on the positioning and adequacy of controls at the Whirring Propellers Company.

## CHAPTER III

# PRODUCTION FORECASTING

Any forecast of the volume of production of a business enterprise for a future period must be based on a forecast of sales for that period tempered with contemplated changes in the inventory of finished goods. Furthermore, sales forecast by products and lines determines the extent to which improvements in production methods may be desirable or, depending on volume, even economically possible. The forecast will also reveal needs for expansion in production facilities and the amount and types of productive labor that will be required.

The sales forecast is usually based in turn on several factors, the determination of which and the degree to which each tends to affect the volume of business of a particular company together constitute one of the major problems of the management of that company. In fact, the foresight of management in this connection often is largely responsible for the success of the enterprise. Any management that has no definite policy for long-range forecasting is inviting business blunders and sooner or later will find itself in serious trouble.

Ask a businessman, "How is business?" Suppose he gives some thought to the question and answers, "Not bad." Well, then, just what does he mean? He probably means that the business his concern is doing compares favorably with that done by other competitive concerns in his industry, and at the same time he believes that the industry in which he is engaged is reacting well compared with other industries. Also, he implies that his business is quite normal for the particular season of the year and that in comparison with the level of general business conditions his business is likewise not unsatisfactory.

Here, then, we have four basic factors that to a greater or lesser degree all have some bearing on the volume of business enjoyed by a particular company and hence must be considered in any forecast of sales and production volume:

1. The effect of competition.
2. The long-term trend.
3. The seasonal fluctuations.
4. The business cycle.

**The Effect of Competition.** A wise management continually asks itself, "What are our competitors doing?" not only that it may be able to keep up with but that it may keep ahead of its competition. Consideration must be given not only to the competitor's activities in the field of new products, the redesign or repackaging of old products, new methods of manufacture, and improvement of quality standards but also to his advertising and sales-promotional work.

But it must not be assumed from the foregoing that the services of a spy or detective are required to ascertain the latest activities of the competitor. Rather, a constant check on the trade papers for the industry, a sales force that contains good listeners as well as good talkers to pick up bits of information from the trade, and a management that cooperates with the trade association for the industry are all that is required to keep a company abreast of the competitive picture.

There are numerous possible competitive factors any of which may be of major importance to a manufacturer. The most common may be classified as quality, price, and service. If a manufacturer is attempting to serve a quality market, he is primarily concerned with keeping ahead of other quality manufacturers in marks of quality such as improved design, new materials, and more attractive appearance in the finished product. If he is attempting to compete in a price market, he is primarily concerned with new manufacturing methods that may reduce material and labor costs and thus permit reduction in selling price. If he is striving to surpass in service, he seeks means for more rapid delivery, repair and maintenance service, and the many "extras" that may cause the buyer to select his product over that of a competitor. These factors require the manufacturer to keep in constant touch with the industry in order to be cognizant of competitive improvements and also to receive suggestions for improvements in his own production and sales activities.

These factors in the competitive picture are constantly changing and interacting one against the other. A manufacturer of heavy machinery may have depended on quality of product and service in meeting competition. Like his competitors, he may have been accustomed to charging full cost of engineering and tooling to the first order, thereby placing no financial dependence on repeat orders. Then along comes a daring and well-financed competitor who introduces a quality product at a greatly reduced price made possible by distributing first costs of manufacturing over possible future orders. This new competition may require drastic changes in production and cost

methods, as well as in sales-promotion practices. Here the competitive picture changes from quality and service to one of price.

Once this information is available, it then becomes the duty of the sales, production, and design departments to interpret the data in relation to their own needs. A promotional scheme of a competitor to push a certain product line may call for a counteracting move by the sales department, which in turn requires that the production department be equipped and ready to meet the new demands for products in that line. To meet or anticipate a change in packaging or product design from a competitor requires action from the design or engineering department and then a forecast by the production department as to the material, personnel, and tools and equipment needed.

**Long-term Trend.** Back in the early nineteen hundreds, when it became apparent to some business leaders that the horseless carriage was not just a rich man's plaything that smoked, snorted, smelled, and went about scaring horses and people but, rather, a coming mode of transportation, far-seeing carriage makers realized that the horse and buggy were on the way out and began to dabble in the manufacture of automobiles. The suppliers of buckles and carriage hardware began to turn to the production of parts for automotive frames and engines. The smiths who previously knew only how to shoe horses and repair chains began to search for other lines of endeavor.

Although these manufacturers certainly did not call this change in their business by such fancy terminology, the long-term trend of the buggy business was definitely downward. The science of reporting business and industrial activity had not at that time been perfected to the degree that it is today. Nevertheless, the fact that that particular trend was recognized without the aid of such reports does not lessen the need for and the use of trend reports today. In fact, it may be said that if reliable reporting of trends had been available about the turn of the century, the makers of carriage parts might have seen the handwriting on the wall more quickly and been better able to make the inevitable readjustment without the high degree of company mortality that actually took place.

Trend information is usually made available periodically to a company by its trade association and less frequently by the Biennial Census of Manufactures. It often enables a company to ascertain with reasonable accuracy the rate of increase or decline of the industry taken as a whole. However, changes in the long-term trend sometimes develop rather quickly, in which case it may not be possible to establish the new line of trend for several years. Prolonged periods of business depression or prosperity also make it difficult to establish the trend

line with any degree of accuracy. The company may also attempt to plot the trend of its own position within its industry, but this is usually more difficult than for the industry as a whole. In cases in which it is possible to establish with reasonable accuracy both the long-term trend line for the industry as a whole and that of the individual company, the two taken in conjunction with each other will provide a

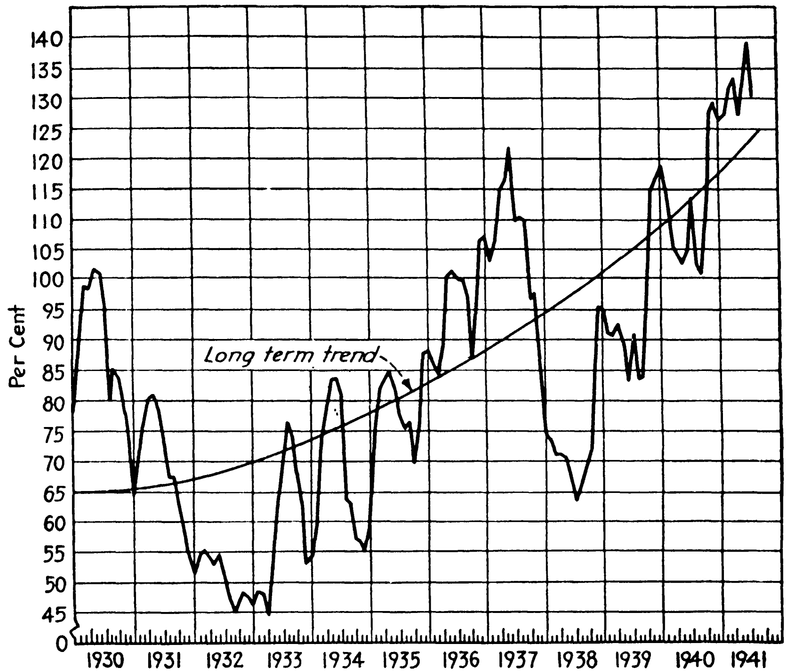



FIG. 3. *Steel's* index of activity in iron, steel, and metalworking industries. Based upon freight-car loadings, electric-power output, automobile assemblies (Ward's reports), and steelworks operating rate (*Steel*). Average for 1926 equals 100, weighted as follows: steel rate 40, and carloadings, power output, and auto assemblies each 20. No adjustments made for seasonal or other trends. (*Steel's Index of Activity in Iron, Steel, and Metal Working Industries taken from Steel Magazine, Aug.* 4, 1941. *The long-term trend line has been prepared by the authors.*)

reasonable basis for forecasting the trend line of the latter for the next few years. The techniques involved call for a high degree of technical skill and judgment. Trend analysis leads to a long-term forecast of sales and, as far as the production department is concerned, facilitates the forecasting of long-term requirements for productive capacity.[1]

[1] The reader is referred to an excellent report prepared and published by the National Industrial Conference Board, Inc., in 1947: "Forecasting Sales," Studies in Business Policy, No. 25, National Industrial Conference Board. This report describes and illustrates in detail seven basic approaches to sales forecasting.

In the United States, where the population has always been on the increase and where the standard of living has repeatedly been bettered, the trend of production taken as a whole has been on the upgrade, and hence it may be said that the trend of the majority of industries is upward. But there are always industries wherein the particular trend differs greatly from the general trend. As we have seen, the trend of the carriage industry was downward while that of the automotive industry proceeded upward at a rate faster than the general trend. The substitution of electric refrigeration for ice refrigeration and the increased use of oil for both home and industrial consumption, thereby replacing the burning of coal, have produced similar relatively steep and counterbalancing trends.

One of the worst circumstances that can befall the management of a concern is to find itself suddenly manufacturing a product for which there is no demand. The managements of some of the now abandoned New England cotton mills found themselves in just such a situation not so many years ago as a result of their continuing to manufacture the same standard lines of cloth while mills in other parts of the country were learning how to create and cater to style changes. It is the position in which the Ford Motor Company found itself in 1927 as advances in appeal, style, and design of motorcars made the Model T a nonetheless reliable but not very salable automobile. That some of the New England mills were unable to fight their way out of their predicament and that Mr. Ford was able to do so is a tribute to the latter and to the subsequent new-model-every-year practice into which he was forced. These are only two glaring examples of failure and success through watching and interpreting the long-term trends or failing to do so, but they point to the need for constant vigilance on the part of business management to ascertain the trend as it applies to each business enterprise and to use that information to the best advantage.

**Seasonal Fluctuations.** Practically all businesses are affected to some degree by fairly regular variations within the course of a year, attributable to changing conditions brought about by the different seasons of the year. A company specializing in greeting cards, for example, receives the overwhelming percentage of its sales orders during a few months of the year as its customers stock up for the Christmas trade. The designing and actual printing of the cards take place months and even in some cases a year in advance; nevertheless, the sales activity is subject to extreme seasonal fluctuations. Similarly, agricultural industries, the canning industries, and the manufacture of

automotive accessories are all to a greater or lesser degree seasonal businesses.

Other types of business activity, as, for example, the manufacture of furniture, boot and shoe production, and the output of pig iron, might seem to be, and in fact are, less susceptible to seasonal fluctuations than are the above-mentioned industries. But these, too, are affected by seasonal changes in general business activity at different times of the year. The activity of the construction industries usually increases each spring, providing a demand for building materials and equipment and leading to increased general employment. During the summer period, production in all lines slackens somewhat as the spring demand becomes satisfied and as vacations become an influencing factor. With the coming of fall, agricultural harvests are reaped, more money is in circulation, and general business activity is further stimulated as pre-Christmas manufacture takes place. Winter usually brings another slackening of activity to complete the seasonal cycle.

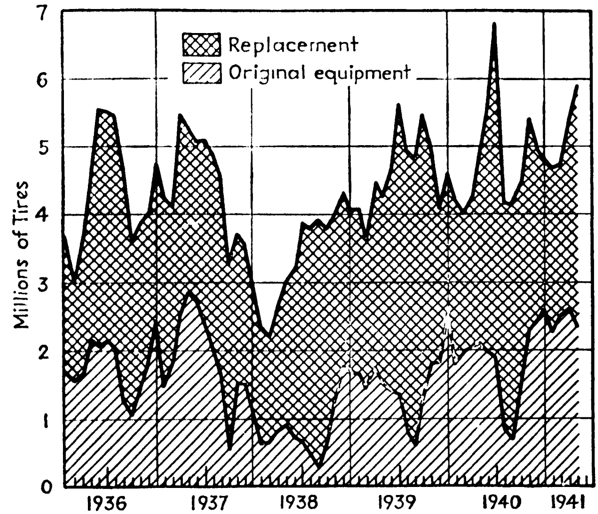



FIG. 4. This chart shows rather well the seasonal fluctuations of automotive-tire shipments, both those made to the automotive manufacturers for original equipment and those sold for replacement. Note the degree of regularity with which the major fluctuations reoccur each year. (*Courtesy of Business Week, June 7, 1941.*)

Seasonal activity is of particular importance to the production department, since it affects the year-round planning. Effective production planning, the optimum utilization of capacity, and a good labor policy all require that production over the course of the year, regardless of the fluctuations in sales, be leveled off as much as possible. This

leveling off of production unfortunately is not possible in all industries. Peas cannot be packed in January, nor can sheep be sheared in November. But in some industries the leveling off of production is possible at least to some degree. The most common methods for stabilizing production throughout the year include production of standard articles and lines for stock, offering special discounts for advance orders, developing new lines whose production peaks coincide with the low points of production in other lines, and developing new markets where sales peaks are out of phase with the sales demands of existing markets. A wise management studies its seasonal variations carefully not only to forecast demands accurately but to find ways and means of leveling its production. A carefully constructed plan in this connection has paid the dividend and bonus in more than one plant.

**Business Cycles.** Anyone who has studied the history of this country cannot help realizing that economic conditions in the United States are constantly changing. What may be the "normal" state of business today is below or above normal tomorrow. Although the fluctuations in individual businesses vary sometimes violently, rapidly, and with much irregularity, nevertheless general business activity seems to follow a regular succession of peaks and hollows over a period of time. The peaks we know as eras of prosperity, the valleys that lie between them as depressions, and the complete wavelike fluctuations in the state of business as business cycles.

An analysis of the business cycles that have occurred in this country in the last century reveals that although periods of prosperity are always followed by periods of depression, and vice versa, the time intervals to complete successive cycles and the intensity of the cycles have varied greatly and seem to follow no definite pattern. Prior to the last depression, the complete cycles from peak to peak had ranged from one to nine years in length. However, the cycle that started with the peak of 1929 has broken all records for duration, and even nineteen years later the height of the next peak yet appears to be indefinite.

In spite of the variations of time and intensity of business cycles, it does appear that the sequence of the phases within the cycle maintains a rather regular pattern. Each period of prosperity is invariably ended by some sort of crisis, which is then followed by a period of decline. This second phase swings into a third or depression phase that must run its course before an upswing takes place to bring back the era of prosperity. However, neither the period of recession nor that of recovery always follows through without interruption. An

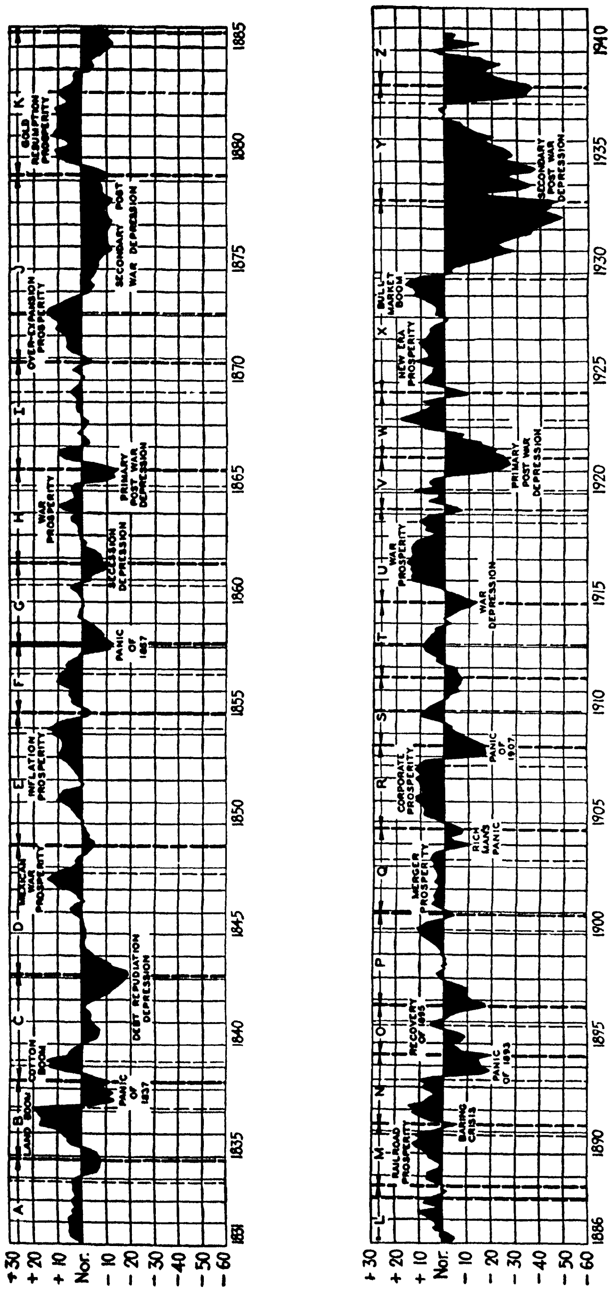



FIG. 5. Business cycles, 1831–1940. (*Courtesy of Leonard P. Ayres, The Cleveland Trust Company, Cleveland, Ohio.*)

apparent recovery trend may be reversed and a renewed depression may set in, and vice versa.

Economists differ widely as to the causes of the cyclical fluctuations in business. Such explanations as mob psychology, the effects of wars, disorders in the national economy, shortcomings in the banking system—all these have been advanced as causes of fluctuations. One pseudoserious attempt was made to show that business increased or decreased with the change in intensity of the sunspots.

But regardless of the causes, business cycles, like the poor, are always with us. We have splurged our way into them, and we have tried to spend our way out, but barring wars or major catastrophes, the cycle has inevitably run its course. Thus it is very essential to the intelligent planning and operation of any business enterprise that the management have before it a picture of the recent changes in the physical volume of business activity of the company and of the industry of which the company is a part. These, when corrected for seasonal variations and if possible for the long-term trend, can be compared with one of the published indexes of business activity that measure changes in such industrial factors as the volume of production of key industries, wholesale commodity prices, freight-car loadings, time money rates, etc. To make the best use of these indexes, it is first necessary to find one that bears some general relation to the business activity of the company or industry concerned. From an analysis of the changes in the activity over a period of time, it is then possible to forecast the effect that a variation in the index will have on the activity of the particular business under consideration. However, great care must be exercised in determining which series has a real correlation with the particular industry in question. An apparent correlation may be merely a matter of chance coincidence over recent years and not a real correlation. Also, changing conditions may suddenly destroy what in the past may have been a real correlation.

To be prepared for an upturn in business activity may mean an opportunity to raise the company to a new level in the industry through the addition of new customers eager to obtain delivery at an early date and through the introduction of new products to meet new demands. What is probably more important is that the company should be able to do this ahead of its competitors. Furthermore, to be able to forecast an upturn in business activity with accompanying increases in the price of materials and wages may enable the company to manufacture to stock in anticipation of a higher profit margin.

Similarly, when the cycle of business activity starts on the downgrade, the company that has been able to forecast with reasonable accuracy has reduced its inventories and thus reduced loss from price cuts. Many a company fails at this turn of activity because of large inventories produced at a high cost that it is forced to sell in a declining market at a loss.

**Effect of Artificial Controls.** The term *artificial controls* as here used refers to private or governmental regulations over volume of production or selling price. Such control by private industry is prohibited by the Sherman Antitrust Act. However, this does not mean that there may not be violations. A mere scanning of the records of antitrust suits will reveal that private regulations and control have been present.

Illustrative of the types of private control that periodically gain public investigation are

1. *Retail-price-maintenance laws*—permitting manufacturers to set and enforce standard retail prices.
2. *Administered prices*—prices fixed by unwritten agreement on an industry-wide basis with allocation of large customers or territories.

Some private controls are legalized, as in the case of number 1 above. It is also true that a manufacturer may control a market, at least temporarily, by the control of patents, processes, or materials essential to production of the product. Usually competition and public exposure will ultimately find a way to break the controls.

Governmental controls have been known in the utilities field for many years. Here a franchise is issued to a transportation company or a light and power company giving it exclusive operating rights within prescribed limits, but at the same time regulating the rates which may be charged for services rendered. A similar type of governmental regulation has existed over the sale of milk. Production of milk for sale to the consumer is limited in some states to dairies that can meet the requirements of health and safety. More important, a producer may be forbidden to sell below an established minimum price.

Governmental controls over production and price became quite prevalent during the depression of the thirties and especially during the Second World War. Some of the depression controls were more in the form of "influence" than direct regulation. The "kill the pigs" movement was one of the earlier influences by which farmers were urged to avoid an overproduction of pork. It was shown that such overproduction would yield less net return than a more balanced

production. To limit the production of grain, farmers were paid from Federal funds for each acre of land that they permitted to remain idle during a given year. This was done in the interest of soil conservation, but at the same time tended to limit production and exercise an artificial control over price.

Government regulation of industry has been limited in the past largely to periods of war. Under war economics, production is pegged or rigidly fixed at artificial levels. Prices and, to a certain extent, wages are controlled, economic incentives become subject to a great burden of taxation, materials are rationed on a priority basis, and property and human liberty are placed at the disposal of the state. There is one objective toward which the resources of the entire country are directed, namely, the strengthening of the military might of the nation. In short, production for consumption is replaced by production for destruction.

The production volume of any industry under such circumstances is complicated by the distribution of government and defense orders and by the subletting or subcontracting of orders to other industries with similar production facilities, as occurred in the Second World War with the manufacture of airplane parts and subassemblies that were "farmed out" to automotive and metal-parts industries. Other dominant factors are the proportion of strategic raw materials, such as steel and aluminum, allotted to any one company; the encouragement, financial or otherwise, given by the government to defense concerns located in areas not likely to be military objectives in time of war; and the pegging or reducing of production by government decree, such as that which took place in the automotive industry. Certain concerns such as the Aluminum Company of America in the aluminum field and Dow Chemical in the case of magnesium, which in the past enjoyed a perfect or near-perfect monopoly, found that the government, in order to bolster the production of needed materials for the good of the country as a whole, had granted financial aid in an emergency for the construction of competitive facilities. Furthermore, those companies that were unable to procure adequate supplies of raw materials for their normal needs or to find reasonable substitutes were thus forced to curtail their production while other companies that happened to be vital to the defense effort were practically forced to double and redouble their normal productive capacity.

Government regulation of industry stands always as a threat to industry. Any period of national crisis invites government regulation as an artificial means toward stabilization. However, the fact that

the threat exists provides added incentive for industry voluntarily to develop means for removing the necessity for government regulation without restricting opportunity for competition. Such action is typified by the motion-picture industry, which developed its own board of censors, popularly known as the "Hays Office."[1] Without such voluntary censorship, government censorship undoubtedly would have developed. However, this, too, may be classified as artificial control.

Any of these artificial controls or influences has a tendency to affect the forecasting of the entire economy. Farm prices affect industrial prices even if only in the resulting increase in industrial wages necessitated by the increased cost of living. Control over one phase of business activity, whether it is to increase or decrease production or price, will usually be felt in many other phases of activity. Production forecasting during a war depends primarily on the trend of that war and the steps that the government feels are necessary to meet adequately the military needs.

The presence of these and other artifical controls over the economics of the country adds another factor that must be considered along with the more naturally operating laws of supply and demand. The best that management can do is to try to anticipate the introduction or withdrawal of controls which more directly affect a business and be prepared to make adjustments in production to meet the resulting changes in the market.

**Consumer vs. Capital Goods.** During a depression people continue to buy staple foods in almost the same volume that they do during good times. Although the average person during such a period has his shoes resoled more times before discarding them, he also does more walking to save automobile or bus costs and thus buys about the same number of shoes as he would purchase during normal times. Yet the situation differs in the case of the more costly articles. People manage to get along with the same old car or with none at all, and hence fewer automobiles are purchased during a depression period. The sale of refrigerators and furnaces declines.[2] Furthermore, very little new housing is erected. During a depression few if any new freight cars are built; the manufacturers of machine tools

[1] See "The Hays Office," *Fortune*, Vol. XVIII, No. 6, pp. 69–72, Dec., 1938.

[2] The fact that the sale of electric and gas refrigerators as well as that of oil burners increased quite constantly during the depression following 1929 does not disprove this statement. These products in 1929 were just then becoming widely accepted by the American public, and the slope of their trend line was sharply upward. However, now that the market for these articles is becoming rapidly stocked up, it may be expected that their sales in future depressions will decrease.

practically close their doors; and the ways and facilities of a shipyard merely go to rot and rust. Why then do the sales of some products hold up during depression years whereas the sales of others approach zero?

The answer can perhaps be best stated by introducing here the economic concepts of *consumer goods* and *capital goods*. Consumer goods are essentially those which reach John Q. Public and which he uses up rather rapidly in home consumption. Capital goods, on the other hand, are those which go primarily to industrial users and are used in producing other goods. It is then rather obvious that the food we eat, the shoes we wear, the automobiles we ride in, the refrigerators that keep our food cool, the houses in which we live—all these are in the consumer classification. But the freight car, the ship, and the machine tools that aid in manufacturing and distributing other products are essentially capital goods.

The question of whether a product is in consumer- or capital-goods classification is important to consider in the long-range forecasting of the product. Any industry making capital goods is very likely to be a "feast or famine" industry. Most, if not all, capital goods are in a sense durable—*i.e.*, they depreciate slowly and require a relatively long time to become worn out or obsolete. Consequently, during lean years the users of capital goods, if they are lucky enough to be sufficiently busy to use the greater part of the capital facilities at their disposal, always find the excuse, "I guess the old machine will stand up for a while longer," and defer the purchase of new equipment "until business picks up." Then, when a boom period starts, such a user finds himself with old and practically worn-out equipment, and the rush that ensues, as other manufacturers like him swamp the capital-goods industries with orders for new equipment, finds the capital-goods industries in no position to meet the sudden demands. It was just such a rush in buying machine tools early in 1941 that caused the term *bottleneck* to be applied to that industry.

One of the best examples of a "feast or famine" business is the shipbuilding industry in general and the Bath Iron Works of Bath, Me., in particular. During the First World War, ship capacity at Bath, as at other yards all over the country, was built up to unprecedented levels. But after the war the bottom dropped out of the demand for ships, and in 1925 the Bath works sold its machine tools, the workers went back to the old Maine agricultural and seacoast occupations, and the Iron Works buildings were for a while turned over to the manufacture of fiber pie plates. Even the boom in the

late twenties failed to cause much more than a murmur in the shipbuilding business, and had it not been for an occasional yacht, trawler, tug, and patrol boat and, finally, in the mid-thirties, a few Navy destroyers, the "know-how" so important to the building of ships as well as to the manufacture of all capital goods might have disappeared at Bath. Then, with the advent of the Second World War, there again came a demand for ships that increased Bath's man power several fold and more than doubled its shipyard capacity. Thus, with a type of business, as described previously, that is subject to such great and unpredictable variations, the difficulties of forecasting volume can readily be appreciated.

We have seen that even different consumer goods react differently during a depression, for people buy food and shoes when they do not buy refrigerators or automobiles. One of the factors that determine the regularity of purchase of consumer goods appears to be the difference in durability of the respective products. The *convenience goods*, such as groceries, cigarettes, chewing gum, all have a low value, are widely available, and have little durability. They are purchased from the store on the corner and are for immediate consumption. When they are used up, more will be purchased. They are mainly branded products, and the reputation of the dealer who happens to make the sale matters little, since the consumer looks for the brand in making the purchase. The so-called *shopper's goods*, under which classification are furniture, clothing, and jewelry, are of moderate value; purchases are made less frequently; and the buyer usually "shops around" from one store to another before making his purchase. The brand of such an article may not be of prime importance, and the reputation of the dealer making the sale is therefore of greater importance. With this class of goods, a greater durability is noted, the articles last for a longer period of time before they must be replaced, and in hard times the period can be lengthened if necessary and the new purchase deferred.

The third class of consumer items is the *specialty items*, such as automobiles, oil burners, and refrigerators. These are replaced at less frequent intervals, are available at fewer places, are of rather high value, and purchases are quite readily deferred when the pocketbook is lean.

From the foregoing it is readily discernible that the greater the degree of durability of the product the greater the fluctuations in volume and the more difficult it becomes to predict with accuracy any future sales volume.

An interesting characteristic inherent in those consumer goods that are fairly durable is that their sales seem to run in independent cycles, the lengths of which are determined by the normal period required to use them up or wear them out. In the textile industry, for example, such a cycle has been noted. The normal period of wear for textiles is two years. Thus, if the sales volume of textiles is high during a certain year, a similar peak may be expected two years later. The normal period required to wear out the average automobile is from three to four years. Hence, under normal conditions, a good year for automotive sales brings about a similar cycle three to four years later. This characteristic of such goods whereby peaks in sales cause similar and subsequent peaks spaced by the average length of life of the article is a factor that is sometimes forgotten in forecasting. Furthermore, it should be noted that the peaks in separate industries are to some extent related. A peak in the sales of the textile industry means that more money goes into the pockets of the textile employees, and hence more automobiles are purchased. A similar peak in the automobile trade in turn releases more money for the purchase of clothes.

It might be questioned why these peaks, rather than veering off into valleys, do not continue to soar upward. The answer is primarily that an increase in demand always brings about an increase in supply, and usually the supply of the article is increased until it exceeds the demand, which condition in itself is sufficient to bring a halt to the upswing and cause a falling off of sales.

**The Sales Forecast.** Once the factors underlying the volume of business activity of a concern have been determined and the degree to which each affects that volume established, the next step is the forecasting of the total sales and the quantitative volume of each line of product.

In cases in which a cause-and-effect relationship can be shown to exist between the fluctuations of some standard business index and the fluctuations of the sales volume of a particular company, it may be possible to work from the changes registered by the index and project the expected effect of these changes on the volume of the particular business. By plotting this projection carefully, a direct reading of anticipated sales volume in dollars or in product units may be taken. This method can be employed only when the time lag between the cause and the effect relationship is sufficient to permit any reading of the sales volume to be translated into manufacturing requirements. For example, a sudden revival of the building-con-

struction industry would have the effect of reviving a specific lumber business in the region in which the change takes place. But because of the hand-to-mouth and contract buying that is characteristic of the building-trades industries, the time lag between the revivals of purchaser and vendor would be insufficient to enable the latter to forecast and become prepared to meet the demand.

Perhaps a more common method of making the sales forecast is through the use of the index and sales curves merely as signposts to indicate any changes in sales that may be expected. However, a watch must be kept for any special circumstances that may destroy the normal correlation that has been shown to exist between the two curves.

Once the total estimated sales volume has been arrived at, it then becomes necessary to break the forecast down into the various product lines. This may be accomplished by using a percentage basis whereby each line occupies a certain percentage of the entire estimated volume. This percentage can be based on the past volume, calculated on a percentage basis, and then applied to the anticipated volume, or it may be based on estimates of the sales executives or the salesman in the field.

Some concerns feel that the foregoing analytical method of taking a figure for the estimated total sales volume and apportioning it out among the product lines is too arbitrary. They prefer to start from the ground up rather than from the top down, estimate the expected volume of each product, and sum up these individual estimates to reach the total forecasted sales. These individual estimates can be based on the compiled estimates of the areas or districts in which the product is sold, with the use of the past sales, the field salesmen's estimates, or even a formal market analysis to arrive at the anticipated volume. Where the salesmen's estimates are used, care must be taken to ensure that the estimates are objective. A salesman is naturally an optimistic creature, and his estimates are often likely to reflect the quantity he wishes he could sell rather than what he will actually sell.

In the past decade there have been two diametrically opposite trends that, strangely enough, have worked in conjunction with each other and that have had a great effect on the forecasting of individual product lines. One trend was toward the standardization of manufactured products. This trend was the logical result of the placing of more and more products on a quantity-production basis. As products gradually became more and more standardized, not only

between the products of any one manufacturer but among the products made by several manufacturers, it was found that the lack of distinguishing characteristics made them increasingly difficult to sell. Hence there came about an opposing trend toward the development of a product that had some distinguishing features. In many cases manufacturers chose the same characteristic to vary—color. It was found that a product standardized in form, size, and performance could be made to look different and to vary in appeal by the simple expedient of painting it different colors. And thus was added one more problem for those individuals on whose shoulders rest the duties of forecasting future volume, for not only must they forecast product lines but must also break down the forecast still further into colors desired. It is sometimes, if not always, possible for the forecaster to omit the additional color subdivision in his forecast by planning the manufacture of unpainted products for stock and later painting them as needed to meet the color tastes of the public for the particular season.

The sales forecast has two prime uses: the planning of the financial needs and operations for the period of the forecast, and the planning of the utilization of productive facilities for that period. The financial requirements are usually detailed in the form of budgets for sales, production, cash, profit and loss, and capital to be expended. The production planning further breaks down the sales forecast into the materials, plant, equipment, tools, and personnel that will be needed to manufacture the products and the quantities forecasted. The subjects of production budgeting and production planning will be discussed at greater length in later chapters.

**Protection against Unanticipated Variations in the Market.** Even with the best of sales forecasts, unanticipated variations may occur which endanger capital and present the possibility of loss of a favorable competitive position in the market. Many of these variations have been mentioned earlier in this chapter: increase in the cost of material or labor; oversupply of the product in the market, resulting in a necessary decline in selling price; or introduction of a greatly improved product by a competitor.

Risk is a natural copartner of opportunity. Capital invested at 2 per cent interest should involve a minimum of risk. Usually the higher the anticipated return, the greater the assurance of at least a reasonable earning on capital. Such is the essential foundation of an enterprise. But one must also seek to protect one's relative

position in the market if one is to assure the continued prosperity of an enterprise. These two purposes are in conflict only in that the first looks to the immediate—the earnings of the present. The second, looking toward long-term development and earnings, may call for some sacrifice of protection of the immediate. Discussed below are only three of many ways by which the manufacturer may seek this protection.

1. *"Tie-in" with the Customer.* This type of protection is particularly applicable to the starting of a new business or the introduction of a new product. Here the manufacturer is seeking a guaranteed market. The arrangement may take the form of a subcontract with an automobile manufacturer for the production of accessories such as heaters, radiators, door handles, clocks, and various other sundry items. In this way the subcontractor, through his contract with the automobile manufacturer, seeks to reduce the uncertainties of sales at least in the short-term future—he is able to manufacture to a specified order. He does not completely remove his risks, however, because he still must face the possible increase in his costs of materials and labor. All he really accomplishes is a reasonable guaranteee of volume involving less risk than merely manufacturing to stock.

Contract may also be made with a large distributor, who may in effect purchase exclusive rights for the distribution of the product for a specified time and at a specified price. For example, a small woolen manufacturer in New England developed a new type of stretcher to be used for the resizing of woolen socks after washing. He was faced with a decision as to possible volume and price. Should he set himself up to produce in large volume for the "five and ten" stores, or should he direct the product toward a more exclusive market with reduced volume but a higher selling price? By contract with a consolidated buying service in New York City, which acted as a procuring agent for some of the better department stores, he sold exclusive distributing rights for a two-year period. Delivery of a specified number was divided over that time. By the contract he was to receive $1 per unit. This gave him a guaranteed market at a guaranteed price.

The principal disadvantage in an arrangement of this sort is that it places too much dependence on one customer. Even if the contract continues to the date of expiration, the manufacturer may then be faced with the necessity of accepting less favorable terms or searching for a new market. To choose the latter after the loss of several

years' contact with the field may be a difficult undertaking. This was one of the worries of manufacturers during the Second World War when their production was being channeled into the fulfillment of government orders. They were fearful that with the war's end they would find that their customers of old had found equally acceptable sources of supply elsewhere.

2. *Provision for Increase in Selling Price.* It has been mentioned that one of most serious risks is the possible increase in the cost of material and labor. As protection against loss resulting from such increases during a period of ascending prices some manufacturers insert a protective clause with all quotations, similar to the following:

> It would be appreciated by the undersigned, when drawing up your purchase order, that you insert the following clause: "Owing to uncertainty regarding the future prices of raw materials and labor entering into the cost of this order, the XYZ Company reserves the right to adjust the price to compensate for increases in material costs or labor contracts. Such price adjustments will not exceed 15 per cent over price at time of acceptance."

3. *Educating Buyers to Standard Lines.* One of the best protections for the future is to prepare for possible cost reduction. During high periods of business activity a manufacturer can sell almost anything that he can deliver. When the tide turns and the market becomes flooded, the customer becomes more demanding as to both quality and price, but particularly the latter. Unfortunately many manufacturers are so busy taking advantage of the peak periods that they neglect to prepare for the less favorable turn of events. On the other hand, the manufacturer who lays his plans well in advance may be in a position to "scoop" the market at the turning point. An illustration may serve to emphasize the importance of educating the buyer for this period of decline.

A manufacturer of builders' hardware found himself forced during the war years to reduce his array of 80 lines of hardware design to 17. This was necessary because he could not get the material to carry the inventory and maintain a plant required by this amount of diversification. However, making the reduction to a limited number of standard lines during a period of high demand had no negative effect on the volume of sales. In fact, it increased his popularity with customers because of his increased ability to streamline production and make delivery earlier than his competitors. Furthermore, with the improvements in production methods made possible by standardization, he was able greatly to reduce cost. This prepared the way for a reduction in selling price when the decline in the market demanded it.

### CASE 3

*The John Matson Company.*[1] Since the earliest days of automobile manufacturing, designers have sought means for adding to riding comfort. One of the innovations of the twenties was the "snubber."

The John Matson Company of Chicago designed a snubber which consisted of a spring enclosed in a case attached to the frame of the car, from which a webbing was suspended and clamped to the axle.

It was planned that the Matson snubber would be distributed through automobile supply companies, the automobile manufacturers not having accepted the principle of the snubber as worthy of inclusion as standard equipment. The demand for the snubber was considered to be good, as determined through analysis of desires of car-owners and by comparison with the products of competitors. Authorization was given for the "tooling-up" of a new plant to be used exclusively for this new product.

To the complete surprise and misfortune of the Matson Company, before the Matson snubber could be released for distribution tire manufacturers hit the market with the balloon tire and completely revolutionized the demand. First sold as extra equipment, the balloon tire was soon adopted by automobile manufacturers as standard equipment. The appeal of the snubber had vanished almost overnight, and the Matson Company's new plant stood idle as a ghost—a reminder of inaccurate forecasting.

#### Preparatory Question

What should the Matson Company have done to

1. More accurately predict the demand?
2. Protect itself against financial loss?

### CASE 4. FACTORS AFFECTING PRODUCTION VOLUME

Of the four basic factors that must be considered in any long-range and intelligent forecasting of production, namely, (1) the business cycle, (2) the long-term or secular trend as it applies to industry, (3) seasonal variations, and (4) the influence of competition, the last three apply to conditions within the particular industry involved, and only the first factor, that dealing with the business cycle, is concerned primarily with conditions affecting the business world as a whole.

The state of business conditions as a whole is commonly measured in terms of some business index that takes certain key industrial factors, assumes some representative year as standard (= 100), and compares

[1] Name fictitious.

present conditions against that standard and frequently against the previous month and year. The most widely used and perhaps most reliable index is the Federal Reserve Board's index of industrial production. This is released monthly, but the exact figures for each month are not available until the early part of the second month after the production takes place. The F.R.B. index is based on the volume of production of 33 significant industries and thus provides a measure of the nation's industrial production.

In 1938, *Time* magazine started publishing the Townsend-Skinner index of business conditions that attempted to reflect not the volume

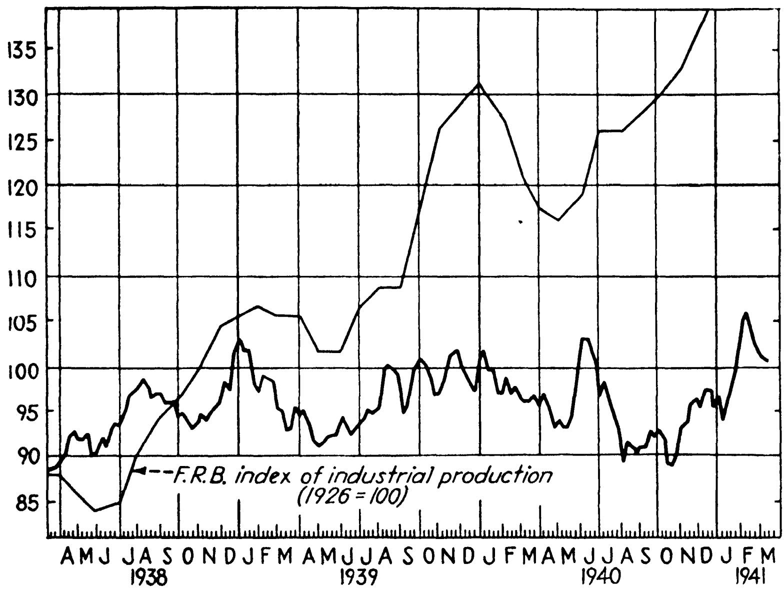



FIG. 6. *Time's* index of underlying business conditions and the F.R.B. index of industrial production

of the nation's business (*i.e.*, production) but rather the changes in the underlying conditions likely to affect the volume of business. It considered such factors as consumer spending, contraction and expansion of credit, fluctuations in inventories, etc., and its purpose was to enable the businessman to recognize trends in business conditions so that he could forecast the changes in industrial production before they actually took place. Figure 6 shows the paths of the F.R.B. index of industrial production and the *Time* index of underlying business conditions for the period 1838–1940. Note that the two indexes seem to differ considerably.

Suddenly, in March, 1941, *Time* discontinued its index of underlying business conditions and substituted in its place a weekly index of industrial production, using substantially the same calibration as

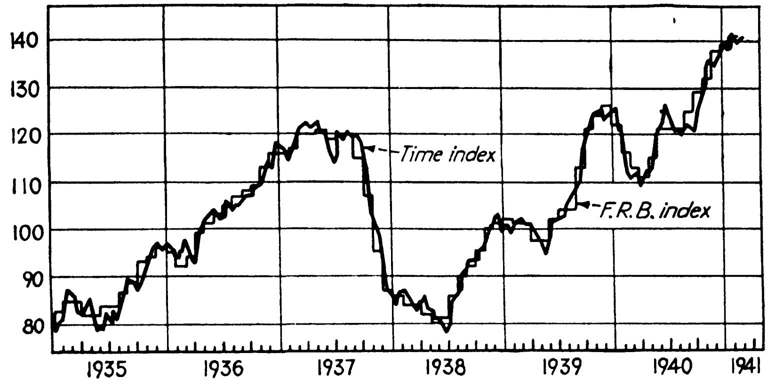



FIG. 7.

the F.R.B. index except that it is only one week behind in the reporting of its figures (see Fig. 7). The new *Time* index is based on a composite of three industrial factors: steel-ingot production, electric-power consumption, and freight-car loadings.

## Preparatory Questions

1. Suggest reasons for the F.R.B. index and *Time's* first index showing different results in 1940.

2. If you were a businessman endeavoring to predict the health of the nation's business as an aid in forecasting your own production, state which index would have been more helpful to you in 1938 and why. Would your answer be any different for 1941?

# CHAPTER IV

# PRODUCT DEVELOPMENT

Product development consists of the steps and phases of activity necessary for the proper development of a product ready for the production department to produce for its eventual sale and satisfactory use.

In the case of a new product, the development will begin with the utilization of basic theory, developed by fundamental scientific research or consumer research, or both, into a design or process. The resulting design or process will then be proved by exhaustive and conclusive tests. These tests may indicate the necessity for changes or perhaps a redesign, with consequent retesting until an acceptable product has been obtained. When product development consists of redesign and improvement of existing products or processes, the necessity is usually dictated by competition, which may be in the form of lower prices, better materials, improved functional operation, greater sales appeal from the appearance standpoint, or by any combination of these factors.

**The Functions of Research.** As many products have been developed from the results of fundamental research, it may be well to define the differences between fundamental research, applied research, and development. Fundamental research is generally conducted in the fields of mathematics, physics, and chemistry, and establishes the truth of new concepts in these fields. Often it is carried on without any specific application in mind; in other cases it is done with a specific goal to be reached in the shortest possible time, as was the case with the fundamental research that led to the development of radar. Applied research is usually accepted to mean research being done for a specific purpose, generally for commercial use. Development takes the results of fundamental and applied research and utilizes them in product designs, which eventually reach the consumer market as new light-weight cooking utensils, attractive plastic products, "ground-controlled-approach" radar for safer airplane landings, or midget radio tubes for portable radios, to mention just a few of the more recent developments.

**Basic Factors in Product Development.** In developing an entirely new product or in redesigning an established product there are certain basic and fundamental factors which must be used as guides, if the new or improved product is to become a satisfactory and profitable article for manufacture and sale. While a detailed analysis of consumer acceptance and marketing is beyond the scope of this text, it can be stated that the desires of the customer, whether an individual buying an electric razor or a huge corporation buying an expensive machine tool, must be met. The customer's criteria may be quality, style, color, finish, utility, reliability, or any one or combination of these features, but he will insist on maximum value in accordance with his standards and within an acceptable price range. Large sums of money are spent every year in market and consumer research in an effort to find out just what the customer wants at the price he is willing to pay for it. While these investigations are conducted principally in the field of consumer goods, there is a growing tendency to adapt these same methods of investigation to some branches of the capital-goods industry.

When a company has other products, care must be taken to ensure that the contemplated product, or changes in an existing product, will not have an undesirable effect on production and sales of the established products. At times it is deemed desirable for a company, in an effort to present a well-rounded line of products to its dealers, actually to develop, manufacture, and market a size or model that must be sold at cost or at only a slight margin above cost in order to come within a demanded price range.

Unless circumstances make it immediately apparent that capital equipment, such as machine tools, forming presses, or special plating and finishing equipment, will be essential, product development should take into account the production ability and capacity of the existing plant. There are, of course, exceptions to this general rule. One would be the case where consumer demand, based on market analysis and consumer research, is shown to be so strong that the product is designed without regard to any existing equipment. Then a plant or plant addition is built for the purpose of manufacturing this particular product. Another exception would be a product that could be manufactured with existing production facilities, with the exception of one or more components which could be furnished by specialty shops acting as subcontractors. The recent war demonstrated the fact that production organizations can amplify their over-all efforts manyfold by intelligent selection and utilization of

subcontractors. These may either be specialists in some particular product, part, or subassembly, with years of experience in a particular field or process, or they may be companies capable of acting as an extension or addition to the contractor's plant, producing certain parts or assemblies under the contractor's direction. Experience gained during the Second World War proved the general feasibility of such working arrangements, but also proved the necessity for close supervision and coordination of subcontractors, not only in their relationships with the contractor but also in the relationships between subcontractors. Joint production control was found to be a necessity, with the contractor maintaining central control records.

**Development Affects All Departments.** As development is truly a cooperative task, all departments should be kept fully informed of the progressive effect of the development upon the existing relations between the company, the plant personnel, the supplier of material, and the dealers. Further, all departments should be consulted by the development department when any steps are to be taken that are an innovation in the light of present practices. Undoubtedly they will meet with many a "But we've never done it that way before!" This is not only true; it is the reason the development department exists. In all cases the sales department must be kept informed of what it will be called upon to sell if the development meets with the success anticipated. Obviously no announcements concerning the new development will be made until it is ready to market, as such news would have a retarding effect on current sales of existing models. This point is especially important in cases where new developments and improvements of a current model are in process. If the newly developed product is to augment or supplement a present line of similar products the situation is different, as such news may instill added enthusiasm for the company's line in the entire sales force, from salesmen to dealers.

While the sales department has a high order of interest in new-product development, it is obvious that those who will be called upon to produce the product have an interest in it at least equal to that of those who are doing the actual developing. The production department must follow it very closely to be kept fully and currently informed of the demands that will be placed upon it. The purchasing department will also want to know what new materials, or new forms of presently used materials, will be requested, as it is possible that the product under development may require materials, or components, of such nature that present stocks of materials may become

obsolete. Again, the situation demands close contact with the treasurer or controller's department, so that the proper financial officers may have current information on estimated costs of development, probable needed investments in new capital equipment or in large purchases of raw material, additions to the pay roll, and the cost of changing over to the new product in the plant, with consequent lag in sales and corporate income during the transition period. These reasons are only a few of the many involved, but will show that the introduction of new product developments are complex and far-reaching throughout an organization, inasmuch as they have an effect on all departments and operations, from the purchase of raw materials to the shipment of the new product and its subsequent sale and servicing.

**Economics of Product Development.** Products can be designed with maximum sales appeal, whether from the viewpoint of utility, form, material, color, or long service, but if the cost exceeds the accepted standard for competitive products, their manufacture, generally speaking, is foredoomed to failure. This is so, just as surely as with the manufacture of products at a reasonable cost for which there is no market, due possibly to lack of utility, unfavorable appearance, or unsatisfactory finish, to name but a few conceivable reasons.

The manufacturer who launches a product-development program is faced with two uncertainties, namely, the cost of the development program and the cost of the developed product when manufactured on a production basis. Of the two, the second is the less difficult to control, as it involves more factors susceptible to reduction by modern manufacturing methods. However, the first of these items always presents uncertainties because estimates of the cost of a development program hinge to a greater or lesser extent on man's capabilities and mental capacity. For example, to put into effect the technical principles that have been developed by a fundamental research program and are now to be translated into a production design, it may be necessary for a skilled mechanical designer to work for weeks on various alternatives before he can develop a design that can be commercially produced within all the limitations of material strength, availability, allowable weight, etc. Despite all of our tremendous technological advances, no one has yet devised a system that will absolutely guarantee that a designer will develop a technically correct design, within cost limitations and of materials that will withstand required usage, by "five o'clock next Tuesday afternoon." Product development, even with the highest grade of scientists, engineers,

and designers that it is possible to hire, is always an uncertain matter with respect to completion of development work within a specified time.

And once a design has been established the end is not yet, for there is still the need to follow out laboratory tests, field tests, and use tests in the hands of company officials, prominent dealers, etc. These often call for modifications which may be of major importance, so again the development engineer must go to work in an effort to "get the bugs out of it." Then, when this has been accomplished and retesting has demonstrated the correctness of the design, the production of a few items of the hoped-to-be satisfactory design is begun on what is usually called a *pilot line.* This serves as a production laboratory, inasmuch as it utilizes the same, or similar, machinery or apparatus that will be utilized for full-rate production. Here the special tools, jigs, fixtures, and gages are used and proved, and once again we may encounter difficulties and resulting small changes in detailed design in order to prepare the new product for mass production. By this time the changes in the product are usually minor, yet accompanied perhaps by time-consuming changes in the production tooling, which may have revealed the necessity for alterations during the production runs on the pilot line. Time and money spent here will, however, be returned manyfold when mass production is finally achieved. Many instances have occurred where not enough time was spent on pilot-line runs to result in the proving of tooling In these instances, as a result of inaccuracies in processing, assembly, or gaging, it has at times been necessary to shut down the whole production line until the defects, now so evident, could be remedied and production resumed.

**The Cost Factor.** In all but exceptional cases, the cost factor is of vast importance in the development and manufacture of products for commercial use. We all can remember the dreams of the advertising men, illustrated by the fanciful drawings of the artists, describing and depicting what life would be like in the postwar world. Most of these effusions appeared during the years of the Second World War when advertising men had plenty of money and time to spend. But two years after the war, few of the widely publicized revolutions in living had taken place. With minor exceptions automobiles looked much like pre-Pearl-Harbor cars and were made of the same materials. Airplanes were larger and faster but essentially the same, with the exception of developments still of a military nature. The everyday use of helicopters by the citizenry at large was evidently

still many years away. Inquiry reveals that the cost element was the basic reason we were not living our postwar lives in the manner predicted by the advertising copy writers and Sunday-supplement writers, aided and abetted by the imaginative artists. The use of light-weight metals was limited by a cost ratio, which was up to ten times that of steel. Even with resulting weight savings, the final cost ratio for given applications was of the order of three to five times that of steel.

While logically accepting facts such as these and building up a volume of business with the economically acceptable materials, no company can afford to sit back and accept present usage and conditions as the only ones possible. Continuous research must be practiced, together with a continued awareness of the research of competitors, or the future of the business may be jeopardized. When lagging sales or competitors dictate a change as necessary, it must be made, or the manufacturer may be forced out of business.

The cost of necessary tools, dies, fixtures, and gages for large-scale mass-production operations is tremendous and often governs product-development decisions by top management in the consumer-goods field of automobiles, refrigerators, radios, etc. The same is true, in a different sense, in the chemical-products field where, in order to manufacture some of the new commercial products recently emerged from the research laboratories, it is necessary either to build a new plant or to reequip a present plant with new process equipment. Yet one of the leading chemical companies, in its report to stockholders in 1947, pointed out that 30 per cent of its sales were of products that either did not exist in 1936 or were not then in commercial production. This rapid transition from research laboratory to process plant is undoubtedly due in large part to the fact that in the chemical industry in the year 1937 there were 303 research workers for every 10,000 employees. Equivalent figures for the petroleum industry at the same date reveal 207 research workers; for the rubber industry 173; and in the radio and phonograph industry, 232 research workers for every 10,000 employees.

From the above it is apparent that the preparation of realistic cost estimates covering a proposed development is of vital importance, not only to the success of the particular product development under consideration, but to the business as a whole. Experience indicates that a new development on which accurate cost estimates have not been made can "bleed" a business into bankruptcy. And even when cost estimates are believed to be as accurate as modern engineering

and cost accounting can produce, there is need for constant vigilance and periodic summaries to keep management informed. When the development has reached the production stage, modern cost-control methods must be exercised in full force to keep the cost of manufacture on a production basis within or under the estimated costs of production.

**Methods of Product Development.** When we consider the methods and procedures in use today in the development of a product, it is interesting to examine the status of what we now term *product development* in the last years of the past century when this country was beginning to hit its stride as a manufacturing nation. We gain some knowledge of the way the manufacturers of that period went about the development phases of their businesses by examining some of the product-design drawings of a large New England manufacturer whose business, established in 1836, has long been a potent force in the process-machinery-building field and is still growing. An examination of the drawings of a bygone day reveals no blueprints made from tracings on linen cloth, because there were no tracings. Tracings would have had no value, as the blueprinting process had not yet been developed. Instead we find one drawing covering, let us say for example, a rolling mill for rolling copper sheets. The single drawing was all that was made for the design; it was an assembly drawing showing all the parts of the mill in place, including the drive gear, which in those days engaged a drive shaft driven by a water wheel in many installations. Each important element of the rolling mill was dimensioned with respect to its major controlling dimensions only. All dimensions governing the degree of fitting or fastening together of adjacent parts are omitted. Under the practices of that time, the superintendent, the foreman, and even the workmen themselves were supposed to know what degree of tightness or clearance of fit would be required for a particular class of work. As we further examine the assembly drawing, we note that it was drawn in ink upon heavy manila paper and also that it was quite pleasing in appearance, as different materials, such as cast iron, steel, and brass were shown in different water colors or crayon to distinguish one from another. After completion the heavy paper drawing was coated with clear shellac to protect its surface from dirt and from fading. Remember that this drawing was the only record the manufacturer had. He had no means of reproducing it, other than to have it copied by a competent draftsman.

It will be noted that, with a total absence of detailed dimensions for an important detail such as that of a drive gear or a shaft, inter-

changeability of parts in case of a breakdown was almost impossible. True, there were certain standards for fits and clearance that were kept either in the superintendent's or in the foreman's notebook, but as inspection gages and gaging practices had not yet been developed there was wide deviation from these simple standards.

Today in that same company we find development and engineering practices of the most modern and accepted patterns. From the basic development layouts, made to full scale or multiple scale in some instances, the various details of a design are drawn up, one detail to a sheet, with the drawings complete in that they contain every single detailed dimension and tolerance required to make the piece. Instructions on the drawing specify the material specification, the metallurgical heat-treatment—if any is required—and provide appropriate space for notations regarding necessary changes and revisions of the drawing. Nothing is left to shop judgment that pertains to the engineering and design exactness of the part shown.

As a matter of fact, this company has gone a step further than merely having one drawing for each detailed part. On certain phases of their products there are repeat operations that require, for example, one operator to devote his time to one operation in machining a shaft. This operation will turn the outside diameter of a flange on the shaft and also face the flange off to a certain dimension. He is not interested in, and can only be confused by, a complete drawing of the shaft showing a tapered portion with a threaded end that has a keyway cut in it. He is interested only in the part of the drawing that shows the diameter of the flange and the location of the finished face of the flange from some datum point convenient for him to use. With these requirements in mind, and in an effort to simplify shop operations as much as possible, the company's production engineers have developed an *operation drawing* that in the case just described shows the shaft in very thin, light lines on the blueprint, but shows the flange in broad, heavy lines, with the finished dimensions that the operator is to achieve shown in bold figures so that his attention is concentrated on that portion of the machining of the shaft for which he will be held responsible.

This is indeed a long step forward from the days of the single design drawing, drawn in ink and water-colored to show different kinds of material instead of crosshatching to an accepted code as is now done. The system of using operation drawings often requires up to ten or more drawings to delineate the various operations, but they are simple and can be made rapidly by experienced tool drafts-

men. In complicated work their use simplifies the operator's problem, and on operation inspection simplifies the work of the inspector.

**The Role of the Company Laboratory in Product Development.** While the above account of the changes that have taken place in the all-important task of getting the information from the development engineer's mind and laboratories down to the shop and into the hands of the man who is actually going to produce the product, shows the vast improvement in methods and procedures, there has been an equally pronounced improvement in applied research. For example, the rolling mill previously mentioned was built, very probably, from rather informal specifications furnished by the purchaser, and these, in combination with the knowledge gained from building other rolling mills for other brass producers, resulted in the final design. No laboratory was available in which trial runs could be made; the only laboratory was the customer's plant after the mill was installed and in operation.

But today one of the largest independent steel producers in this country maintains a laboratory where small pilot runs of steel can be made to new and exacting specifications. Paralleling its pioneer work in the development of rolling mills for the copper and brass industry, the previously mentioned New England builder of process machinery worked with the early rubber manufacturers and furnished some of the first rubber-milling machinery. Now an acknowledged leader in this field, this company has established a laboratory equipped with every important type of rubber-processing machinery and runs tests to prove the feasibility of its use for new products or new compounds that are brought to the company by chemists, inventors, or companies without extensive laboratory facilities. Although technically rubber is considered a plastic, common use of the word *plastic* has come to mean materials other than rubber, including the large group of synthetic organic materials that become plastic by the use of heat and are capable of being formed to shape under pressure. Natural and synthetic resins, cellulose derivatives, and proteins constitute the principal bases from which the materials popularly known as "plastics" are made. The New England builder of process machinery was quick to evaluate the similarity between the requirements for machinery for processing rubber, either natural or synthetic, and the materials in the synthetic organic group, and accordingly entered the plastic machinery field. He later equipped the laboratory with machinery for processing these plastics, open and subject to the same usage as before. Here, then, is a specific stage in the development

process, where a manufacturer maintains a laboratory not only for his own use but also for the use of customers and potential customers, with the commercial view in mind of possibly determining and proving the practicability of new materials for which the company would be the logical source of supply of required process machinery.

This laboratory service is duplicated by various companies in the steel, aluminum, brass, and wood-products industries and in the highly technical field of electronics. Thus the chain of development is begun with new basic material or new uses for existing materials; from this grow new developments in process machinery and equipment, and in consumer goods. Commercial laboratories and those at educational institutions are also available for use by companies without these facilities in their own plants.

**Development in Nondesign Industries.** Obviously industries such as the soap, soup, canning, and meat-packing industries do not require a product-design department, as their product development is carried on in their chemical laboratories and the results are reduced to formulas, written specifications, and manufacturing instructions. Associated with the laboratory developments on these products are the problems of production, involving machinery for steam and other processing; inspection, wrapping, packaging, and shipping. The development of this associated equipment is often of as much importance as the product itself, since without the machinery it might be economically impossible to manufacture and market it. Thus the plant-engineering and equipment-development departments of these industries rank in equal importance with the product-development departments.

The clothing industries maintain design departments but operate on a system very different from the others. In the men's clothing industry for example, design sketches are created from which sample suits are made up and evaluated. If accepted, the patterns for the various trade sizes are drafted, and from these the various pieces comprising the suit are cut from the material.

**Relationships between Development and Production-control Departments.** Since production control, when fully and adequately utilized, serves as the central coordinating agency, the production-control activity should keep fully informed of all development work, its character and status. Only in this way will the production-control department be able adequately to evaluate the demands that will be made on it when and if the proposed development is released for manufacture. This often leads to involved situations, with serious

effects on master schedules for the production of standard items already in production or, in the case of development that will supersede a present product, requiring a wholesale revamping of present processing and scheduling. One of the production problems that had to be met and successfully solved in the Second World War was the change-over from the design of a weapon or instrument that had been outmoded to a new design, while at the same time minimizing any change in the rate of flow of vitally needed equipment to the forward areas of both theaters of war. This was accomplished only by close coordination between the development, production-engineering, and production-control groups, and although it was achieved under the duress of military necessity, the necessity still exists in today's competitive markets, though of an economic rather than military character.

Production control has a definite mission, during the development period of a product, in maintaining control of the development process. Although, as has been pointed out in preceding paragraphs, no one can absolutely and positively schedule completion dates for the accomplishment of problems involving a great amount of original thinking, inventing, and design, there still must be maintained a control over expenditures and a record of accomplishment of the project to any given date, embodying a record of progress or lack of progress. Only in this way can responsible executives obtain a complete picture of the status of the project and apply remedial measures as may be required.

If we will envision control as the chart, compass, loran, and radar equipment of a ship about to begin a voyage, we will come very close to the functions of control in industry. The master of the ship has his orders and knows his course with its usual hazards to be encountered, but with modern navigational aids he can hold his ship to it, being forewarned by these modern aids of the existence of unexpected hazards and able to alter the course accordingly. So it is with the proper utilization of modern control techniques in industry.

### CASE 5. PRODUCT DEVELOPMENT

### Effects of New Product Development on All Departments

*The National Union Rubber Company.*[1] This company has had under partial development for a period of almost ten years a tubeless tire for passenger automobiles. During the war years the shortage of natural rubber halted development work, but it was resumed as soon as a supply of natural rubber became available.

[1] Name fictitious.

The company has now reached a point where it feels that the tubeless tire is ready for the market, as exhaustive laboratory and road tests have proved it to be a safe and satisfactory tire. However, in its present status the tire could be used only as new equipment on new cars, since it requires special rims on the wheels and is of such increased cross-sectional area that provision must be made in the design of the car body for clearance between the tire and the car fenders. This particularly concerns the *turning radius* of the car, *i.e.*, the radius of the minimum diameter of circle in which the car can turn.

Other problems from a production viewpoint are (*a*) new plant equipment for producing the tire, especially in the final molding and curing operations; (*b*) the obsolescence of the equipment now used for making tubes for conventional tube tires; (*c*) a training program for production and inspection personnel; (*d*) the education and indoctrination of process engineers and production-control personnel in the required processing, routing, and scheduling; (*e*) reduced quantities of items comprising work-in-process; and (*f*) reduced number of items of finished stock of completed products to be carried in stock.

The sales department, advertising department, and service department, together with purchasing and shipping departments, are all involved in this new development; in fact, there is not one department that will not feel the impact of this radical change in tire design.

## Preparatory Question

Assume that you are an industrial engineer employed by the National Union Rubber Company. In the past you have shown a capacity for investigation and analysis, and on the basis of this you have been directed to prepare a report on the general subject of how this new tubeless tire for passenger automobiles will affect the following departments: advertising, sales, service, purchasing, production, production planning and control, and accounting (or controller). Include in your report a long-range forecast of how this new development of the tubeless tire will affect the tire industry as a whole.

# CHAPTER V

# PRODUCTION ANALYSIS

**The Need for Production Analysis.** The preceding chapters have defined control, have shown the necessity for the inclusion of control functions within an organization, have described the principles of forecasting, and have presented the story of the steps generally taken in the development of a product. Using the concept of control as an important tool or aid to management, we find upon reflection that the degree of refinement we expect to obtain from the use of controls will depend upon the degree of refinement to which we carry the analyses of the processes utilized in the production of a product, be the product an automobile, a chemical, or canned fruit. The degree to which this can be carried depends in turn largely upon the possession of such data, in the case of metalworking, as are necessary to route a job to the proper machines, specifying and providing for the proper machine setup and production tooling, prescribing a predicted time requirement for each operation and, finally, providing for inspection and release to shipment or stock. Thus we see that when we set up a control method we must at the same time set up a method of analysis of the various steps to be taken, and apply both theoretical and practical knowledge and experience to a study of these steps.

This analysis is known as *production analysis* and may be defined as follows:

*Production Analysis* is a study of the processes or operations to be performed during the production phases of the manufacture of a product, resolving them into individual or separate operations, together with their accompanying material movements, all to be undertaken with an exact knowledge of the existing plant, plant equipment, and personnel.

**Requirements for Production Analysis.** Production analysis is a highly technical process and demands personnel with technical training and experience that has made them fully conversant with the production problems associated with a particular type of product or class of work. The performers of this function are known in various plants as process engineers, methods engineers, production engineers, etc. In

general, their functions are about the same, but we shall refer to them here as production engineers.

There is a definite time requirement with respect to the utilization of the services of a production engineer by the product-development or product-design departments: he should be brought in on the design of a product in its earliest stage, aiding and advising the product designers with respect to proper and practical production practices, and especially with respect to the utilization of the existing equipment of a plant.

Day by day the specialization of industry is becoming more pronounced, and within industry the tasks and duties of those employed are therefore being specialized in a like manner. For instance, years ago the draftsman or designer in a manufacturing plant was more often than not a mechanic by trade who, by means of an education perhaps better than that of the majority of his shopfellows, had been transferred to the drafting board from his machine or bench. He was fully conversant with the design of the company's products and equally well informed regarding the production processes then practiced in the company shops and in community shops. However, the situation today is very different. Now it is uncommon to find a draftsman or designer who has had actual shop experience, since the highly scientific nature of present-day developments is so advanced and so rapidly changing that the modern technical graduate who elects design engineering as his field of endeavor has difficulty in keeping abreast of all developments in the field. Conversely, the technical graduate who makes industrial engineering or production engineering his choice cannot hope to keep conversant with present-day methods of stress analysis, electronic applications, and other developments that apply to design engineering, any more than the design engineer can hope to keep practically informed of the latest developments in production engineering and processing.

Many large corporations and government bureaus and departments have recognized this widening gap between the drawing board and the shop and have instituted production-engineering departments, staffed by thoroughly trained and experienced production engineers, who in most cases have technical training plus an exact knowledge of the latest production practices in their field, and—what is just as important—a very intimate and exact knowledge of the capacity and limitations of the company's plant and its equipment.

**Duties of Production Engineering.** A typical production-engineering function would operate along the following lines: When au-

thority has been released for the development or improvement of a product, and as soon as the design has reached its first stages on the drafting boards, a production engineer is detailed to follow the project from its inception to the completion of the signed and approved drawings and their release for manufacture. Production engineers, specialists in their respective fields, are available for consultation and advice on applicable production processes, including those with specialized experience in the making of patterns, or in foundry work in iron, steel, and the nonferrous metals, specialists on welding, plating, and painting; and specialists on the capacities and limitations of all forms of machine tools.

In short, every effort is made to work into the design, while it is in process, those practical production elements that can spell the difference between the success or failure of a newly developed product. In this way the manufacturing tolerances that the product design must have for reasons of interchangeability, service, or safety will be specified on the drawings and to such limits that they can actually be maintained by the shops. Under the old system of allowing each draftsman to be his own production engineer, too many design drawings reached the shops bearing manufacturing limits and tolerances that could not be reached, let alone maintained, in any shop.

At times, in the development of new products, there will arise a necessity for very exacting manufacturing tolerances that must be met and held if the product is to function. These requirements must then become the subject of special research and study by the production engineers, and will probably involve the purchase of new production equipment, or perhaps the development of entirely new production processes.

**Design and Production Standards.** The utilization of commercial standards for bolts, nuts, taper pins, and many small components is common practice in all companies, but this may be expanded within a company to include standard parts that are common to several lines and classes of product. For instance, in the design and manufacture of electrical-control apparatus there are many coils, contacts, etc., that are used in combinations of apparatus for various uses and in varying combinations of electrical phase, frequency, and voltage. The large automobile companies, producing several makes of cars and several models of each make, have carried this unit-standardization plan to very successful use.

The advantage of this standardization of parts to production control is of course obvious, since it lends itself to the manufacture of

these parts in large lots, gaining not only the benefit of low-cost mass production, but a reduction of the number of jobs in process that must be controlled.

The use of standard production methods is of equal importance to the use of standardized units or parts, since it permits the use of standard tooling, standard inspection requirements, and—perhaps of greatest importance—the development of standard skills on the part of workmen and machine operators. The use of standardized production methods, however, requires that standard conditions surrounding the production operation be maintained. A workman cannot be expected to meet a production standard of quality on a worn or defective machine, nor can he be expected to meet a production standard of rate of production if the conditions surrounding his machine or workplace are inferior to those under which the standard was established.

## PRODUCTION AND ASSEMBLY PROCESSES

**Processes in General.** The manufacturing industries embrace literally thousands of different production and assembly processes, varying with the type of product made. Thus the refining of petroleum utilizes various chemical processes that are in truth *production processes*; the same statement holds with respect to the manufacture of paper, steel, brass, and aluminum, to name but a few. However, for the purpose of our text it is necessary to select the processes for one industrial group, and the group commonly known as *metalworking* is therefore selected. This section of industry represents huge capital investments and enormous manufacturing plants, employs millions of people and produces such universally known and used products as refrigerators, radios, automobiles, locomotives and cars, ships, and airplanes, to list but a few of a large group of finished products. Students and readers interested in industries other than those of the metalworking group will find a comparable list of processes employed in the industry of their choice in any good technical book covering that field.

**Metalworking Processes.** Fundamentally, three processes are employed in the metalworking industries:

1. *The hot working of metals*, which includes the making of forgings; castings, made either in sand or in permanent molds; hot rolling, to produce rods, structural shapes, flat plates, sheets, and strips; hot drawing to produce tubes and pipes; extrusion, also used in the manufacture of tubing and special shapes; welding, a process accomplished by means of intense application of localized heat, whether electric,

gas, or by furnace heating of the parts to be welded, although the latter is almost obsolete.

2. *The cold working of metals*, which includes shearing; punching; bending; cold rolling, to produce rods and strips, sheets, etc.; drawing, by the use of presses equipped with proper dies to "draw" or shape a part; spinning, usually used on thin sheet metals and tubing; embossing and coining, both of which utilize the plastic properties of metals by forcing them to flow under great pressure in presses into predetermined shapes and patterns as governed by dies.

3. *Chip-producing processes*: those carried out on the master tools of all industry, *i.e.*, machine tools of all types and classes. These remove metal in large or small chips or particles to produce smoothly formed surfaces to predetermined shapes and dimensions. Included are lathes for turning, boring, or facing metal parts to round forms; planers and milling machines for machining flat surfaces; drills for drilling holes; boring mills for boring circular forms; shapers for producing either flat or geometrically formed surfaces, as does a gear shaper; tools for broaching, a form of milling that may employ a formed broach or cutting tool; and grinders which remove small particles of metal by the high-speed cutting action of an abrasive wheel, and by which work of great accuracy can be produced.

**Assembly Processes.** Assembly processes vary with the nature of the product and may consist of the hand assembly of minute parts into a subassembly for a small electronic device or, in the same industry, the assembly of a number of completed subassemblies to form a complete product, such as a radio. In these examples the assembly work might be done on a moving conveyor belt, with several assembly stations for assembling the subassemblies into the complete product.

An extreme instance might be the assembly (usually termed the *erection*) of a locomotive, where each part is assembled separately into the final whole. In the case of the radio sets used as an illustration, all parts are light and small and can be easily assembled by girls, while in locomotive erection huge cranes of 75- or 100-ton capacity are required and mechanics of long experience in that particular field must be available.

**Production Capacity Required.** As the development of a product progresses and as production engineers analyze the production processes that will be required for its manufacture, the next important question to be answered is: How many shall we plan to build and at what rate of production? The answer to this usually comes from top management via the sales department, whose responsibility it is to set

up sales budgets and to implement them by selling the product. As a matter of actual practice, the rate of production has a great bearing on the character of the production processes used and may often affect the fundamental design and the kind of materials utilized. For instance, if the anticipated sales of a product were to be at a rate of 100 units per month, it might be good production design to utilize a weldment as a component part, whereas if the sales were to be at a rate of 500 units per month, this higher rate of production might make it economical to utilize a forging and to make the investment incident to the acquisition and use of drop-forging dies. The same reasoning would apply to machining operations: a rate of production of 1,000 units a month might indicate that certain operations would be performed most economically on a hand-operated turret lathe, while a production of 10,000 units a month would necessitate the use of a multiple-spindle automatic turret lathe.

The production rate has a great bearing not only on the selection of machine tools and plant equipment, but also on the number of work-holding devices—jigs, fixtures, cutting tools, and other special equipment that will be necessary to get maximum acceptable production from standard machine tools and equipment. The utilization of this special tooling is essentially the keystone of mass production, as practically any product can be produced in lots of one or more in a modern toolroom equipped with very accurate machine tools and manned by toolmakers and mechanics of the very highest order. But production rates and costs would be prohibitive. It is these special tools and fixtures, together with their utilization on standard machine tools and their operation by operators instead of by highly trained and paid toolmakers and mechanics, that demonstrate the principles of (*a*) the transfer of skill from the operator to the machine, and (*b*) the division of labor. These two principles are among the most important in modern industry; it was not until they were recognized and set to work that manufacturing grew from the old handicraft days into the days of mass production, resulting in "more goods for more people, at less cost."

Rate of production is the basic requirement on which all production-engineering analyses are based, and since all decisions as to plant layout, plant equipment, and personnel hinge upon it, this must be established early in the development stages of the product design.

**Selection and Utilization of Plant Equipment.** The number of cases where a plant is actually built and equipped around a product that either has just been developed or is in the final stages of develop-

ment is small indeed compared with the cases where a new development must be manufactured in an existing plant and with existing equipment or a small percentage of new equipment. Both situations, however, have many points in common and the same procedures are applicable. After the development of a product has reached a stage where its basic functioning has been passed on as satisfactory and the materials have been decided upon and the rate and volume of production set, the production engineers develop operation- or process-sheets for all parts, subassemblies, and final assemblies. These operation sheets list all operations that must be performed on machine tools of certain types, classes, and sizes; welding machines of certain characteristics and capacities; induction heaters of specified frequencies and kilowatt capacities, etc. The operations are then listed according to the kinds of equipment on which they are to be arranged and by the type of process, turning, boring, or milling. If the production layout is to be planned for making a particular product and no other, the operations may be performed in their proper sequence on machines to be used only for this purpose. This sometimes means a duplication of machines and equipment, but such duplication may often more than pay for itself by reduced costs resulting from greater production.

From the operation sheets actual or calculated times for each operation may be obtained, and from these times the resultant production rates, both from individual machines and from the production line as a whole. This will show the number of machines necessary to achieve a required volume and rate of production, and will indicate their types and sizes. If such a study shows only part-time utilization of a machine that is necessary because it is capable of performing an essential operation, further study may develop the fact that it is possible to have the work done on a machine already in the plant, provided the work load on it permits time for the operations essential to the newly developed product. If this is not possible, there is always the alternative of subcontracting the work involved in the operation to another manufacturer with open capacity. Either of these alternate plans usually results in added complications for the production-control department.

The next step is to select the required types, sizes, and makes of machines that this study has shown to be necessary. Usually the majority of these machines are already installed in the plant and the question of their availability will be determined by the work load scheduled for them for other products. When the purchase of new

machines is necessary, it is usually desirable to duplicate the machines already installed in the plant, unless they are obsolete with respect to type and general performance. This precept should be followed only as modified by an evaluation of all considerations involved, for obviously the best machines available at the time they are to be purchased should be selected.

In the selection of machines and equipment necessary to produce a given product there will be times when the greatest production of the required quality and quantity can be attained only on a single-purpose machine. A *single-purpose machine* may be defined as one that, by its design, construction, and ease of loading and unloading the work, is best adapted to perform an operation or series of operations on a component part of a product. In the automobile, refrigerator, and other mass-production industries, single-purpose machines are often built and installed on the basis of "writing them off" the equipment account when that model of the car or other product is superseded by a new model consisting of different components. In other words, the savings in production by the use of this special single-purpose tool are so large that the tool is considered as an expendable item. However, the same principle is applied in industries where production does not reach the heights enjoyed by the automobile, refrigerator, washing-machine, and radio industries, to mention a few in the consumer-goods field. Special-purpose machines are often used in industries devoted to more modest production and in many cases are rebuilt machines or standard machines altered for single-purpose use. Much will depend upon the mechanical ingenuity of the production engineer and the shop supervisory forces, often aided by worth-while suggestions from intelligent and interested workmen.

**Tools, Jigs, Fixtures, Dies and Gages.** With the types and sizes of machine tools and items of plant equipment to be utilized now determined, it next becomes the task of the production engineers to provide the machine tools and equipment with special tools, jigs, fixtures, and dies to fully utilize the potential production capacity built into the machines by their makers. The final step is the design of special gages and measuring equipment to check the accuracy of the work produced. These special tools and devices may be defined as follows:

*Tool.* A small tool, appliance, accessory, or device used in doing work on raw materials on semifinished or finished parts and products.

*Jig.* A work-holding tool or device that both clamps the work and guides cutting tools in performing their work; usually applied to drilling and reaming operations.

*Fixture.* A work-holding tool or device that holds work in proper position and relationship while machining, welding, or assembly operations are being performed.

*Die.* A special tool used in a metal-forming press for blanking out (cutting) shapes from sheet metal, for forming them, or for shearing, perforating, or rolling sheet metal. A die is also a mold in which plastic products are formed in a press, either by impact or by extrusion—both under pressure.

*Gage.* A gage is a tool or device or instrument used to check the accuracy of the work performed. Gages may be of two classes: first, those used in the shop for the inspection of parts and components as they come from the production machines; second, those used for final inspection only. As most gages are subject to wear, there may be a third classification, termed a *master gage,* which is used only for the checking and calibration of the production and final inspection gages.

The amount of money that should be spent upon tools, jigs, fixtures, and gages, depends in great part on the quantity and rate of production. Generally speaking, the expenditures for this tooling will be reflected in a saving in cost of production of the component parts of the product and also in the cost of the assembly operations. However, there is a point of maximum return that will vary with every individual case and will require the exercise of good judgment by the production engineers. In the case of some products, the inherent accuracy that must be built into them in order to achieve satisfactory operation dictates, once and for all, the amount of special tooling required. In these cases, it would cost as much to tool up properly for a production of 100 per month as for 1,000 per month.

Although the most common error made by production engineers is that of providing too little special tooling, there are also many instances of overtooling. This has upset the economic balance between the cost of direct labor to be charged to production operations and the cost of providing machine tools and special tooling to perform these operations. No general rules can be laid down that would be applicable to all situations, as there are too many variable factors to be considered. However, a trained production engineer, assisted by an able cost accountant, can easily reach an answer for a particular case in a relatively short time.

The amount and character of this special tooling is of prime interest to the production-control department, as the time to design and make special tooling and gages will have a decided effect on the scheduling of the product. Also, the use of this special tooling will have a bearing of equal force on the rate of production, which in turn affects the routing and scheduling.

**Plant Layout.** Having determined the processing necessary to produce the product, which in turn determines the machinery, plant equipment, special tooling, and gages that will be required, the next phase of the production engineer's work consists of making a plant layout which will locate the various machines and the assembly and inspection areas needed to produce the product at the determined rate of production. But such a layout must be made with full consideration of the associated departments and functioning of the plant, *i.e.*, receiving, stores, shipping, toolroom, toilet facilities, and cafeteria. In addition, other factors must be taken into consideration, as they have a distinct bearing not only on the efficiency of the production-line layout, but on the personnel problem as well. These include the building itself, its heating, ventilation or air conditioning, and lighting.

The ideal condition in a plant-layout problem is to be free to submit the requirements in the form of a new plant, built around the necessary machinery, plant equipment, and services. But this is a rarity. Usually the problem is to lay out the production line within the confines of an existing plant, using existing equipment. The next most common condition is to install additional necessary equipment, perhaps removing some obsolete or overage machines. Building alterations and small additions are sometimes required in these instances. Thus we find the production engineer usually fitting his theoretical layout into existing buildings with all their inherent problems.

The engineers will strive for an arrangement of machinery that will provide the nearest approach to a progressive flow of work from operation to operation. If the product is an addition to an existing line, this cannot always be accomplished without seriously disturbing the flow of work for other products. If, however, it is a new product with a rate of production greater than that of existing products, the requirements of this new product will probably dictate the location of equipment on the plant layout.

The determination of what is the best plant layout will vary with the product, the production operations necessary, the available building, the available operating and production personnel, and many

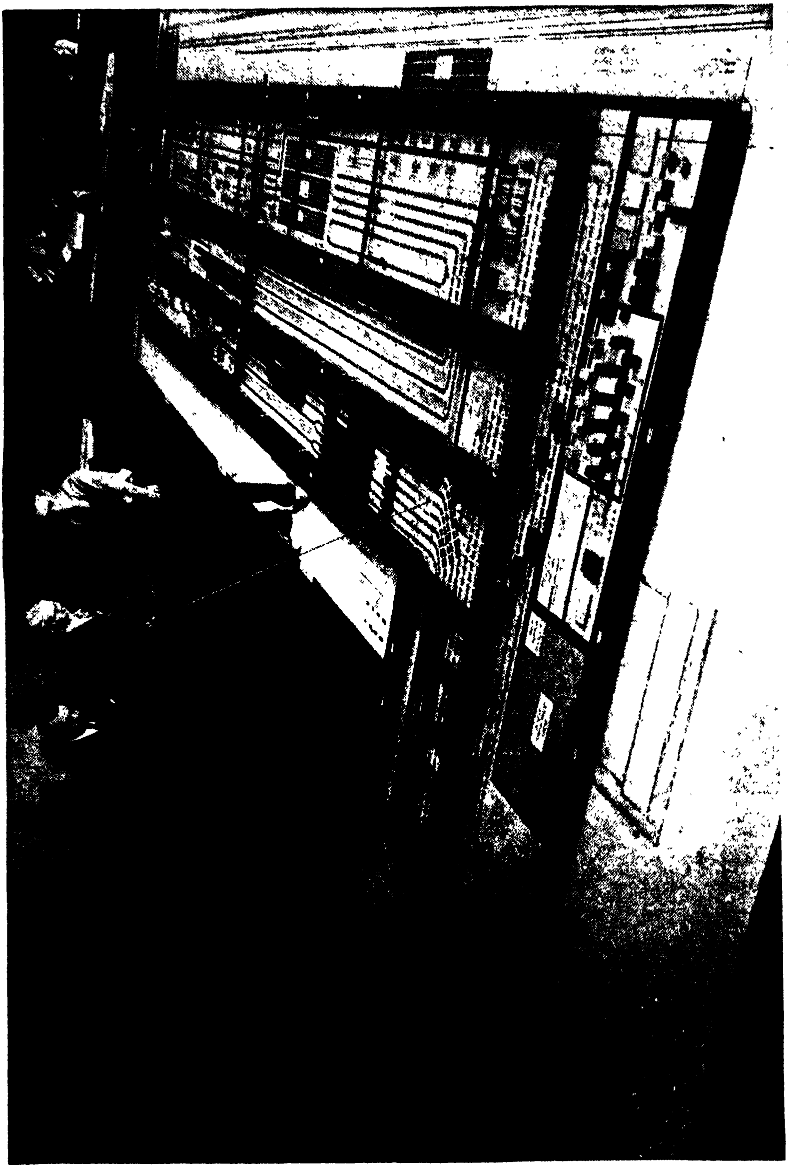


Fig. 8 A plant-layout model used as an aid in planning flow of work. (*Courtesy of Automobile Manufacturers Association.*)

local factors. Therefore each layout problem must be settled on the basis of the results of the best individual study available.

The magazine *Factory Management and Maintenance* has listed the following points as the results to be expected from a good plant layout:

1. Provides definite lines for travel of work.
2. Provides shortest practical distance of travel between operations or assembly.
3. Reduces the amount and cost of material, handling, equipment, and labor.
4. By rapid movement, cuts down cost of work in process.
5. Reduces amount of work in process.
6. Reduces inventory in storerooms.
7. Most fully utilizes equipment and personnel.
8. Conserves floor area.
9. Simplifies the routing of work.
10. Reduces personnel and cost of production control.

A very useful tool for the production engineers, when engaged on plant layout work, is the *flow process chart* described more fully in subsequent portions of this chapter. This enables the analyst to put in orderly form on paper the necessary operations in their sequence, shows all necessary transportation expressed in feet of movement, and indicates all storage points, inspection points, etc.

As the time element is of such great importance in production, being secondary to quality only, the production engineers and the production-control department must concern themselves very seriously with this factor. Without knowledge of the time required for processes and operations there could be no reasonable approach to the vital question of the rate of production. It is therefore essential that standards be established for determining production time required for both processing and assembly operations.

**Establishing Standards for Production Time.** The study of industrial operations for this purpose is called *operation analysis*, and the principal methods used in this work are *time study* and *motion study*.

Time study may be defined primarily as the art of observing and recording the time required to perform each detailed element of an industrial operation and "leveling" off the results into a practicable, attainable standard.

Motion study may be defined as a study of the movements—whether of a part, a machine, or an operator—involved in performing an operation. The purpose is to eliminate useless motions and to arrange the useful motions in proper sequence. Motion study is, in effect, a refined form of routing, and may be closely connected with the movement of work through the plant, from raw material stores and from operation to operation.

In general, motion study precedes time study, and it must be remembered that the object of both is to establish standardized performances.

It is obvious that standard performances, however carefully prepared, cannot be realized unless all the conditions under which the operation is performed are also standardized and do not vary materially. A lathe cannot be expected to make the same performance with a driving motor having a burned commutator as with one in good condition, nor can the worker produce good results if he is surrounded by adverse conditions. Operation analysis must therefore be intelligent and must consider the operation, the material, the workman, and the conditions that exist at the production center and the surrounding areas.

In general, the following steps must be taken in making such a study leading to *operation standardization:*

1. Investigation and standardization of the production center and its surrounding conditions.
2. Investigation of the elements of the process to ensure that no unnecessary movements are made and that the best sequence of elements is followed.
3. Making time studies of the details of the operation. (This may not always be required, as reliable records over a long period may give the same result.)
4. Analyzing time studies (or reliable existing records) and establishing standard performances by means of instruction cards, operation drawings, or some like method.
5. Developing a routine procedure that will ensure the accomplishment of the required performance and also the permanence of all necessary standard conditions.
6. Determining the financial incentive necessary to interest the workman in the project.

**Investigations Preliminary to Operation Analysis.** There are several sound reasons why a preliminary survey is essential before making an operation analysis. The first, and most important, is the psychological aspect of this work. The success of any innovation in any industry depends to a large extent upon the degree to which it is possible to enlist the confidence and sympathy of the foremen and the workmen concerned. It is by no means a simple task to convince workers that their interests are being served when time and motion studies make possible increased production. One of the best methods used to introduce operation analysis into a plant that has never used

it is the *conference method.* The program literally has to be sold to both foremen and workmen. Added to the conference should be a class in time and motion study, in which both the foremen and representatives of the workmen seriously study the objectives and techniques to be used; this will go a long way toward attaining the cooperation and understanding needed. Absolute honesty must prevail and the precept that it is not a program for getting increased production at the expense of the workman must be strictly adhered to. Management should recognize that the workman rightfully expects to share in the benefits of increased production. When standard times are once set they must be maintained unless the conditions of the operation or the production center change fundamentally. A broken promise is long remembered and full cooperation from workmen cannot be expected unless a reputation for square dealing prevails.

Next, we find that the second reason for a preliminary survey is to familiarize the man who is to make the analysis of the operation with tools, methods, and operations in current use, and their relations to each other. If a good routing system is in operation, the relation of the several processes will be satisfactory, but in many cases a rearrangement of the sequence of the various processes may be necessary for the best results. The surroundings of each production center should also be studied so as to remove any conditions adverse to production. Records must be taken of production under existing conditions for the purpose of comparison with production under new conditions.

A third reason for a preliminary survey is to gather data on each machine's general condition and the feeds, speeds, cutting capacity, and other significant factors. The problem of predicting performance would be greatly simplified if all machines of similar capacity had similar characteristics: that is, for example, if all 36-inch lathes had the same lead screws, back gear ratios, feeds, etc. But they haven't, and although in some cases a good degree of equipment standardization can be accomplished, the practical fact remains that we must use what we have, even though it involves a large amount of work in collecting the required data. Information must be obtained on the handling time of all machines, *i.e.*, the time required by the operator to set, change, and otherwise operate the machine. Material-handling time must also be examined—what is the average time of waiting for crane service, for example?

Now, upon observation and reflection we can see that all of the requirements set forth for operation analysis do not necessarily involve time study. They are merely the requirements of good shop manage-

ment, but we all know that they are rarely observed to the extent outlined here. Time study is not used by all commercial manufacturers, for many reasons. But the companies who do not, and who expect to remain as competitors in their particular field of manufacture, use this general approach up to the actual time study itself. Their substitute for time study is observation plus reference to records of previous jobs. Many highly successful bonus systems are in operation without detailed time studies being made except at the request of the workman who believes he has been given a job with too small an allowance of estimated standard time. There have even been cases where the workman has called the attention of the time setters to jobs on which they have erred in setting too liberal a standard time. Such a situation can result only from mutual trust and respect, and in the case mentioned comes from the irrevocable rule of management that after a time is set, following the first run, it will never be changed downward unless

1. There has been a design change in the part, altering the basic operation.
2. New and improved tooling, fixtures, etc., have been designed and built.
3. New and improved machine tools or equipment have been provided.
4. A change in material has been made.
5. A change has been made in quantity to be machined.

**Motion Study.** With the survey of the conditions surrounding the production center disposed of, there remains a preliminary investigation of the type of operation itself, to see if it is performed in the best possible manner, that the sequence of detailed operations is correct, and that they are efficiently performed. This may involve an examination of the methods and movements of the operator, usually called motion study. Anyone at all familiar with industry knows that on most jobs different operators, if left to themselves, will do their tasks in entirely different lengths of time. Differences of 100 per cent in the time two operators take to do the same task are not at all unusual. It will generally be found, after study, that such operators are utilizing entirely different methods to perform the job. Analysis will reveal that one has discovered a number of short cuts while the other is performing a large number of useless or cumbersome motions. After the best method has been developed, the next step is to teach all the operators the new, standardized method.

The simple motion study of a job in its general elements may reveal many losses and useless motions without any consideration of the time element. It isn't necessary to have a stop watch in your hand to know that a worker who must walk a dozen feet to get material for his machine or to deposit the finished product of his operation can have his workplace arranged more effectively. General motion study is likely to yield valuable information for the improvement of standards of equipment, and the elimination of useless motions is often one of the best ways of reducing fatigue.

In 1911, which was about the time of the great increase in interest in management, Mr. Frank B. Gilbreth set forth in a small book called "Motion Study," the results of his investigations in the field of bricklaying, being at that time himself an engineer connected with the contracting business. He had made a detailed analysis of the cost in time of letting the hod carrier drop the bricks somewhere near the bricklayer, so that he was forced to take steps to the pile to get a brick, then back to the point where he was going to lay it, give it several "twirls" so that the right side for laying would lie upward, etc. Gilbreth also found out that there were a large number of similar waste motions in the placing of mortar. From these he developed certain standard equipment, such as a pocket for holding the bricks at a proper level, with the right side up, and a "nonstooping" scaffold, which changed in height as the wall was built up.

Observation of bricklaying as practiced today will show that Gilbreth's observations did not make the impression on this ancient art that might have been expected. In general this has been due to the attitude of labor, which has been strong enough in some instances successfully to resist logical change and improvement.

However, the field was opened up and interest in such economies of effort soon spread to all industry. It was quickly discovered that many of the motions made by workmen were useless and resulted only in fatigue and wasted time and energy. In many cases motions were too rapid and complex to be segregated from connecting motions and timed by the human eye with the use of a stop watch. So Mr. Gilbreth used a motion-picture camera together with a clock of special design, which he called a *microchronometer*, to investigate such rapid motions. The clock has a dial about 30 inches in diameter, with only one hand, and makes 20 revolutions a minute. The perimeter of the dial is divided into 100 parts, so that each division on the dial represents one two-thousandth part of a minute as the hand moves over the face of

the clock. From this we get the name *micromotion*. The clock is always placed near the workman performing the operation to be studied, so that as he is photographed the clock appears in the picture; the film thus shows the smallest movement and a record of the time required to perform it. The analysis can be studied at leisure and seemingly unnecessary movements detected. Mr. Gilbreth, in the later years of his life, made some very interesting motion studies by attaching an extremely small electric lamp bulb to the hand of the operator and energizing it by using very flexible wiring. The light level in the vicinity of the workman was then lowered and motion pictures taken of the operation, the light from the small lamp tracing the movements of the workman's hand. The results were equally interesting and helpful.

Although the greatest area of adaptability and use of motion studies is in the field of high-rate continuous production of consumer goods, —as radio parts and radio manufacture, automobile accessory manufacture, drug and cosmetic processing and packaging, and fountain pen and automatic pencil manufacture—the principles may be applied to any field. Motion study also has been made of the more common surgical operations, such as appendectomies and tonsillectomies, with the end in view of keeping the incision open for the very minimum of time. Studies have likewise been made of the loading, firing, and case ejection of guns in the Navy. The range is almost unlimited.

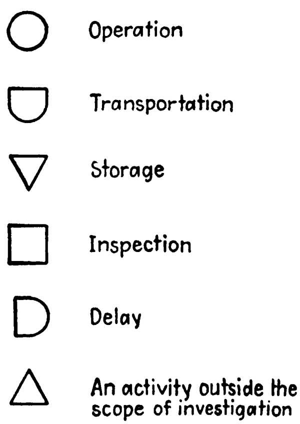
In the field of heavy-machinery manufacture on a job-order basis, one instance comes to mind where the production staff from vice-president down to production-control clerk were required to attend a twelve-week course, given once a week. True, the same operations were not present in building main pinion-stand drives for rolling mills as in the assembly of radio sets, but the net result was satisfactory as it made everyone "motion-economy-minded" and finally resulted in a complete relocation of about 60 per cent of the tools in the main machine shop, doing away with long movements of parts in process between operations and resulting in time savings on delivery schedules up to 20 per cent. This is the usual result of an educational effort of this kind, whereas no person or organization can come into an established concern, which has proved its ability to produce, and specifically take the superintendents, master mechanics, and foremen by the hand and say, "Here, do it this way!" Let us grant that their continued presence in the organization indicates their ability to do their job; usually all that is needed is for an outline of principles to

fall upon their fertile gray matter, and the first thing we know, we look up and witness the application of those principles on the work at hand in that particular shop.

**Process Analysis.** Since there has been a tendency to limit the term *motion study* to the details of the workman's job, the term *work simplification* is coming into accepted use as that which best describes and embraces the fields of process analysis, simple motion study, and micromotion study. *Process analysis* may be defined as the subdivision of a manufacturing process into its constituent operations and attendant material movements, so that each operation and handling of material may be studied and its necessity and effectiveness in furthering the process under analysis determined.

The presentation of a process analysis is best made by one or more types of *process charts*, employing symbols by means of which the study can be carried on. A process chart is a graphic representation of events, and information pertaining to the events, occurring during a series of operations.

Symbols are used to represent the events, and those most commonly used are as follows:




Although the use of the above symbols is practically standard among production engineers, there is one school of thought that has discarded symbols and uses the capital letters O, T, I, S, D, standing for operation, transportation, inspection, storage, and delay.

There are several forms of process charts, the first being the *operation process chart*, which subdivides a manufacturing process into its separate operations and inspections. The second stage is the *flow process chart*, which introduces the details of storing, handling, and

moving the material between manufacturing operations. Shown on this chart is a graphic representation of the sequence of all operations, transportation, inspections, delays, and storage occurring during a process or operation, and it includes information considered desirable for analysis—for instance, the time required and the distance moved.

On the surface-hardened, cast-steel rotors of Banbury mixers, a machine used in the processing of crude rubber, there are over 130 operations from rough castings to finished rotors. By means of process charts and rearrangement of certain equipment a total of 700 feet of travel was saved and storage stops cut to under 100.

Again industry has the late Frank Gilbreth to thank for a useful tool, the process chart. As it presents facts graphically and clearly, action results.

In this connection the story has often been told of the time Frank Gilbreth approached the chief executive of a manufacturing concern that had retained his services for a study of their manufacturing troubles. A long process chart was rolled out on the executive's desk, but with scarcely a glance at it he said, "I can tell you right now I won't approve it, whatever it is. It's entirely too complicated." "You're right!" said Gilbreth, "only this happens to be a process chart of your present procedure!" The executive finally admitted that the chart showed him more than he could have gathered from several hours of discussion.

## CASE 6

*The McKee-Landis Corporation.*[1] This company is an old, established builder of process machinery equipment and instruments for the chemical industries. In the past, much of this equipment was utilized in the basic chemical processes and required no great precision in manufacture. However, present demands are for equipment built to higher precision standards of manufacture, due to the increased complexity of chemical processing. Added to this demand for higher quality of manufacture is a diminution in numbers of their old-time, all-round mechanics due to deaths, retirements, etc. The only available labor supply in any quantity is of machine operators only, mostly men who were trained as operators in the wartime operations of the McKee-Landis plant or in neighboring plants.

Manufacturing difficulties multiply; there is continual dissatisfaction and wrangling between the assembly department, the inspection department, the production shops, and the engineering depart-

[1] Name fictitious.

ment. Several orders have gone out to the customer that were not satisfactory in operation in the customer's plant. Delivery promises are seldom kept and production scheduling is absent.

The general manager knows that the future of the business is at stake and that something must be done to modernize their manufacturing methods—with no great investment, however, in new plant equipment. Further, he realizes that the class of labor he has is the best he is able to get. His experience and many consultations with other executives convince him that the great need of his organization is greater emphasis on the principle of the transfer of skill from the worker to the tool. He realizes that dimensioning of working tolerances and fits as determined by the draftsmen without consultation with shop executives is wrong in principle, and that the days when expert mechanics in the shop could correct and forestall such errors are gone.

### Preparatory Question

Assume that you are an industrial engineer and have been hired by the general manager of the McKee-Landis Corporation to install and operate a suitable production-engineering and production-control department. The general manager, although faced with a serious condition in the company's business, realizes that hastily devised plans will not be most effective, and has therefore requested you to make an analysis of the problem and then submit a report embodying a proposed organization for the new department, showing the method of operation, number and grade of people required to operate it, availability of these people within the organization, etc. In short, he wants you to submit a workable plan for remedying the manufacturing difficulties with which he is faced.

# CHAPTER VI

## RELATING BUDGETING TO PRODUCTION

The profits derived from operating an industrial enterprise, in spite of a popular concept to the contrary, are not linked directly to production volume. A "boom" period does not always ensure a black profit-and-loss statement, nor a "bust" period a red one. Rather, profits are lassoed to efficiency or the effectiveness with which the enterprise is operated. Efficiency is sired by knowledge—knowledge that brings answers to such questions as these: Which products or lines are now profitable to produce, and which are unprofitable? What departments are costing more money to operate than they should, and why? How does it happen that a slight increase in production schedules sometimes brings a tremendous increase in material tied up in the plant as in-process inventory?

Knowledge in these areas is handed to the plant manager on a silver platter known as the *industrial budget*. It enables him to locate the "rat holes" down which his dollars are going. Discovery of the rodent hangouts, and—to carry our analogy still further—eradication of the rats, are the two main functions of the industrial budget. It is a management tool for constructing in advance the over-all plan for operating the enterprise over a definite period of time: a month, a quarter, a year, or several years.

The budgeted plan may be compared to the military strategy prepared by a general and his staff before going into battle. Like the military plan, it makes use of available facilities, personnel, and equipment, and it plans operations to meet expected conditions. Likewise, it offers alternative courses of action to meet changing conditions, even to the extent of planning a "strategical withdrawal," should this later be deemed necessary. Finally, it presents a picture of the results that may be expected from the operations planned.

Any budget is a yardstick for measuring today's experiences. It is not merely a history of past things, but rather is a means of controlling current operations, expenses, and costs. The budgeted plan must be followed by a comparison of actual vs. forecasted results. In the event that the variance between the two is of an unfavorable nature, corrective action is generally called for if full effectiveness of the

budget is to be realized. In this manner yesterday's plan for the future, based on the history of the day before, leads today into control for tomorrow.

## TYPES OF BUDGETS

The industrial budget, strictly speaking, is composed of an interrelated series of budgets covering sales, production, and the financial aspects of the enterprise.

**Sales Budget.** The sales budget is usually prepared first and is based on the sales forecast together with the record of past sales. It usually shows a breakdown by products or product lines together with their estimated sales for one or more months, quarters, or years. Allied with the sales budget is the budgeting of selling expense, in which the cost of future sales is estimated by sales territories according to monthly or quarterly periods. Advertising costs are frequently included in this expense budget, although some companies prefer to make up a separate budget for advertising and sales promotion.

**Manufacturing Budgets.** Once the sales budget has been prepared, the next step is to budget manufacturing facilities in such a manner that production will meet the estimated sales.

| Production Budget for Month of ________ | | | |
|---|---|---|---|
| Item | Present production | Planned production | Percentage change |
| *A* | 3,500 | 4,000 | +14 |
| *B* | 5,000 | 4,000 | −20 |
| *C* | 3,000 | 6,000 | +100 |
| *D* | 5,500 | 5,500 | — |

Fig. 9.

1. *Production Budget.* This budget establishes the contemplated production, usually by line of products, individual product, or component part per unit of time—day, week, or month (see Fig. 9).

Production budgets may range from a general-summary plan of the entire production picture down to an individual and specific budget for each manufacturing department or unit. The usual procedure, however, is to budget individual departments first and then to compile the general production budget by summarizing the subsidiary departmental budgets. But regardless of the method of preparation, the production budget serves as the basis for the remaining manufacturing budgets.

The quantities budgeted to be produced will differ from the estimated sales by the amount of inventory variation contemplated. For example, if it is deemed wise to increase the stock balance of finished goods, it will be necessary to manufacture more material than is anticipated will be sold. If it is desired to decrease the stock carried, less material will be budgeted into process. Furthermore, the production budget usually endeavors to smooth out sales fluctuations, in order thereby to make the most effective use of productive capacity. This leveling of seasonal or other short-term business peaks and valleys is usually accomplished by manufacturing to stock during periods when there is a lull in sales volume and using that stock to cover sales during periods of heavy demand.

2. *Materials Budget.* An outgrowth of (1), this budget computes the amount of raw material required to manufacture the desired

MATERIAL NO. CRS-1.50 DESCRIPTION: C.R. steel 1½ inch diam.

MATERIAL REQUIREMENTS—YEAR 1948

| Product number | Budgeted production | Q'ty mat'l per M* | Material requirements |
|---|---|---|---|
| K3B | 10,000 | 100# | 1,000# |
| L5A | 50,000 | 25# | 1,250# |
| M3C | 500 | 200# | 100# |
| | Total | | 2,350# |

* Includes 10% allowance for scrap during manufacture.

FIG. 10. Budget of materials compiled by accumulating individual product requirements

quantity of product. Sometimes this figure can be arrived at by multiplying the amount of material required per product unit (with due allowance for the normal amount of scrap encountered in manufacture, or *scrap factor* as it is usually called) times the units of production budgeted (see Fig. 10). Where a material item is used for a range of products or sizes, it may be easier to rely on past consumption taken from the inventory records and projected into the future according to the percentage of change anticipated. This latter method is particularly useful in estimating important supply items such as grinding wheels, tool bits, and processing chemicals, which must be frequently budgeted. The application of unit costs to the materials budget and a summarizing of the results furnish the total anticipated material cost for the budget period.

3. *Budget of Facilities.* Also derived from the production budget, the budget of facilities determines the number of machines and other items of equipment and tooling, as well as manufacturing space re-

quired, if the anticipated production is to be realized. Where the manufacturing process is serialized, it is usually a simple matter to work from standard production per hour per machine (with due allowance for normal idle or "down" time of the type of machine in question) and arrive at the number of machines required (see Fig. 11). However, for job-shop production the budgeting of facilities may be extremely difficult unless a log or running record is kept by type of machine of the machine-hours required on each to manufacture orders already received as well as those anticipated during the budgeted period. Any necessary budgeting of tooling or of space requirements can be prepared from this machine estimate.

4. *Budget of Employees.* It is but a short jump from the budget of facilities to one of employees. The number of production operators to run the required machines can be calculated readily. Nonproductive employees—servicing, maintenance, inspection, and clerical—are often estimated as fixed percentages of production employees, the

FACILITIES BUDGET FOR MONTH OF ________

| Type mch. | No. mchs. available | Std. production per hr. per mch. | Std. hrs. per week per mch. | Std. production per wk. per Mch. | Units req'd per wk. | No. mchs. required |
|---|---|---|---|---|---|---|
| Vert. mill. . . . | 5 | 6 | 40 | 240 | 1,000 | 4.2 |
| W. & S. Lathe | 2 | 100 | 40 | 4,000 | 1,000 | 0.25 |

FIG. 11.

percentages being determined empirically. This budget permits the personnel department of the plant to know and plan in advance the hiring, transferring, and retraining of employees required of it during the budget period.

An outgrowth of the employee budget is the budget of labor cost for the period under consideration. A close approximation to the anticipated cost of labor can be arrived at simply by multiplying the number of employees anticipated by the plant-wide weighted-average hourly earnings (with due regard to overtime pay and to increases or decreases in general wage levels, if such are anticipated), and by multiplying this result in turn by the anticipated man-hours of work (see paragraph 5 below). A more laborious approach is the calculation of labor costs by products using production-cost standards for the operations involved in the manufacture of each product.

5. *Budget of Man-hours.* A certain flexibility in facilities and number of employees required can be obtained by budgeting their hours of work. The general practice is to start out with the optimum

hours of work[1] and then add overtime hours or reduce the schedule temporarily as the production schedule may later warrant.

The work-shift policy of the plant or industry also has a considerable bearing on this budget. Single-shift operation is commonly preferred for hand or assembly operations or where equipment cost, and hence the machine-rate charge against the operation, is low. Multishift operation is desirable where the utilization of equipment sixteen or twenty-four hours per day serves to reduce materially the hourly machine-rate charge on that equipment, as would be the case for large and expensive equipment items. Furthermore, long and costly start-up and shutdown charges in some industries, notably steel finishing, papermaking, and some chemical production, require continuous processing. Such factors as these for the enterprise in question must be considered in budgeting the hours of work.

6. *Maintenance Budget.* While not a universal practice by any means, budgets for planning machine down time and maintenance costs are sometimes employed. Every machine should be cleaned, repaired, or adjusted periodically. In most enterprises an allowance is made for such down time in computing the number of machines required (the facilities budget). However, for certain major items of equipment, such as air compressors, transformers, and the like, or for serialized or line production, it is frequently desirable to budget this down time so as to minimize the interruption to production. Furthermore, such a budget then aids in estimating the maintenance costs for the period.

**Financial Budgets.** Financial budgets project the expected monetary receipts and disbursements for the period under consideration. The profit-and-loss budget, which serves this purpose, is usually based on anticipated income derived from the budgeted sales and on anticipated outgo shown in the manufacturing budgets, this outgo being composed of material, labor, and overhead or burden expenses required to operate and maintain the productive facilities for the desired level of production.

Some concerns, however, work from, rather than toward, the financial summary. They start with the profit they hope to make, calculate the sales volume necessary to create this profit, and budget operations on that figure. Unfortunately, this practice is not always possible, or even desirable, since it tends to invoke some wishful thinking. Perhaps the best method is to work toward the profit-and-loss

[1] As this volume is written, forty hours per week is generally accepted as the basic work schedule in industry.

budget, and if the profit appears to be too small or the loss too great, an analysis can be made to change or modify certain expenditures or quantities to arrive at a level of operation that gives the greatest profit or the least loss.

The cash budget is important to the control of the future cash position of the company. It is useful to the controller or other financial executive in arranging for loans with the bank, since it enables him to plan in advance the time at which additional cash will be needed, the amount that will be required, and the duration of time necessary to repay it. In this connection it might be added that the profit-and-loss and cash budgets as well as the supplementary sales and production budgets are of great aid to the controller in showing the officer of the bank the reason for and the soundness of the loan desired, as well as offering proof as to the anticipated ability of the company to pay back the loan at the stipulated date.

The budget of capital investment is occasionally used to plan changes in plant capacity or equipment. It is particularly useful in periods of expansion to plan an orderly sequence of expansion as well as to point out the financial requirements for such a change.

Once the financial budgets have been determined, it is then possible for the financial officer to make out a budgeted balance sheet showing the financial condition that can be expected at the end of the budget period as a result of the anticipated operations. When this is compared with the actual balance sheet for the end of the previous period, significant changes in financial ratios can be calculated to show management to what extent the financial condition of the business will be affected during the period.

## PREPARING THE BUDGET

**Length of the Budgeting Period.** As has been stated previously, the length of the budgeting period may range from one month to several years, although that most commonly employed for financial purposes is one year. However, it is common practice to use the fiscal or model year rather than the calendar year. The automotive manufacturers, for example, usually start their budgeting year with the introduction of the new car models. Similarly, the highly seasonal business of making the controls for push-button radios requires a budget period that starts with the manufacture of the parts for each new model of radio introduced. Usually the length of the budget period depends on the turnover of money and for this reason should include at least one complete cycle of operations so that money tied

up in raw and in-process materials may undergo one complete liquidation. Another way of stating the same thing is that the minimum budget period should be equal at least to the time from the purchase of the raw materials until the finished product is shipped. Other factors that influence the budget period are the stability of the product sales and of general business conditions. Obviously it is more difficult to budget operations during an unstable period, and for this reason it is frequently advisable to shorten the budget period during such times.

Of course, the budgets discussed in the foregoing are essentially short-term budgets dealing with operations of the immediate future. However, in times of expansion or contraction in particular, it is frequently desirable to supplement the short-term budget with a plan for a longer period of time in order that a better long-range perspective may be obtained.

**Constructing the Budget.** The officer administering the budget in a concern may vary from the works manager to the controller or treasurer. Or this duty may be turned over to a subordinate of one of these officials, in which case the official controls only the general budgeting policies.

In constructing the budget, perhaps the most common procedure is for the sales manager, the works manager, and the controller or treasurer to form a temporary or permanent management committee and to meet in conference to formulate general budgetary policies. At these conferences general estimates and forecasts of sales may be presented by the sales manager for adoption or criticism. Once the general estimates and policies have been agreed on by these officials, they may then separately prepare their specific budgets. The sales manager can compute his sales and expense distribution, and the works manager usually confers with the plant engineer, the purchasing agent, and his departmental foremen as to the breakdown of the departmental budgets. In some plants each departmental head is required to compute his own budget, the feeling being that this practice gives the foreman a sense of management responsibility; also, if he makes out his own budget, it is much easier to put pressure on him to live up to it. But where this is not done, it is common practice to have the operating head indicate his approval of his budget by signing it.

A second conference or perhaps a series of additional conferences may be necessary to make desired changes in the major sales and production budgets so that the financial status of the company will

be affected to the best advantage, with due consideration to other factors involved. Then the controller consolidates the budgets and prepares the financial budgets for approval. Once the budgets are approved, they are usually distributed to the operating heads concerned so that they may have before them at all times a statement of what their operating costs should be.

## OPERATING THE BUDGET FOR THE CONTROL OF COSTS

It should be remembered that the purpose of financial budgets is to furnish a continuing control over labor, materials, and expenses. This is accomplished by regular and frequent comparisons of actual with budgeted figures. The operating heads can be given the actual figures at set intervals and allowed to make their own comparison for their operating unit. They are expected to offer an explanation for any wide variances from the budgeted figures. The operating head knows just what expenditures are allotted to him, and the burden of proof rests with him to show due cause for deviating from them.

It is, of course, to be expected that changing conditions will affect certain elements in the budget so as to require periodic revisions to compensate for unforeseen events or for any errors that affect budget figures. Unexpected changes in sales volume or sales distribution frequently occur, or changes in manufacturing methods or in the product itself often introduce entirely unexpected factors. Hence the budget must be periodically reviewed to take these changes into consideration.

In general, the budget should be considered as a standard or guide that is prepared for each department concerned. A company that has employed a budgetary system for a considerable length of time and that has practically eliminated errors in estimates might expect its personnel to adhere more closely to the budgeted figures than would be required in a company where budgeting is relatively new. But in either case, the control resulting from the budgetary procedure comes from analyzing the variations between the actual costs and the estimated figures and locating the causes of such variations.

**The Static Budget—Its Limitations.** Up to this point in the discussion, the general principles considered apply primarily to what is known as the *static budget.* In the drawing up of static budgets, all figures are based on the average anticipated sales and production-volume level. As long as the actual volume does not vary greatly from the anticipated figure, the results may be expected to be valid.

But if an error has been made in forecasting so that the actual figures depart from the expected level, if conditions change so as radically to affect the volume, or if the seasonal or other variations introduce wide fluctuations from the average, the results obtained from a static budget cannot be expected to be very reliable.

The reason for this can be shown by a simple illustration. The man who owns an automobile knows that the more he uses his car per year, the more it costs him to operate it per year but the less it costs him per mile. Figure 12 reveals that in the operation of an automobile, as in the operation of a business enterprise, there are certain costs that are fixed regardless of whether the car is operated 5,000 or 20,000 miles. Insurance, taxes, registration, and garaging costs are fixed, regardless of number of miles. Then there is another type of cost that is semifixed—*i.e.*, certain elements of the cost are constant, regardless of the extent of operation, but the remaining elements depend primarily on

| Miles per year | 5,000 | 10,000 | 15,000 | 20,000 |
|---|---|---|---|---|
| Insurance, taxes, registration, etc. | $ 65 | $ 65 | $ 65 | $ 65 |
| Garage | 75 | 75 | 75 | 75 |
| Depreciation and obsolescence | 110 | 110 | 130 | 130 |
| Tires, gas, oil, repairs, etc. (at $0.03 per mile) | 150 | 300 | 450 | 600 |
| Total cost | $ 400 | $ 550 | $ 720 | $ 870 |
| Average cost per mile | $0.080 | $0.055 | $0.048 | $0.043 |

Fig. 12. Effect of number of miles an automobile is operated per year upon cost of operation per mile.*

the usage of the vehicle. Last year's car, even though it may never have been used, is worth less than this year's model. This results from the obsolescence factor, which bears no relation to use but depends solely on changes in style and appearance as well as on improvements made in the design of the current model. Hence this element is constant, regardless of the extent of operation. Usage of a car, however, produces some wear and tear on the vehicle, which is reflected in a loss in value known as *depreciation*. Thus this element depends solely on the usage of the car. The combination of these two elements results in a combined cost that, although it does fluctuate some with the use of the car, is semifixed in that it does not vary directly with that use. The expense of tires, gas, oil, and repairs, however, depends directly on the miles over which the car is used and is essentially a variable cost.

Just as the cost of operating an automobile per mile depends on the number of miles the car is used, so does the cost of producing one unit

* All figures are approximations.

of goods vary with the volume produced. The cost of operating any business is composed of fixed, semifixed, and variable elements The fixed element, sometimes known as the *stand-by cost,* includes taxes, insurance, fixed charges, and even the watchman's wages. These are the expenses that continue even though the plant may be shut down for a while. The semifixed or, as it is sometimes called, the *semivariable* cost, is that which results from the decision of management to operate the plant. The items that make up the semifixed element depend on the volume of business to some extent but do not fluctuate directly with changes in volume. They might include, for example, the salaries of

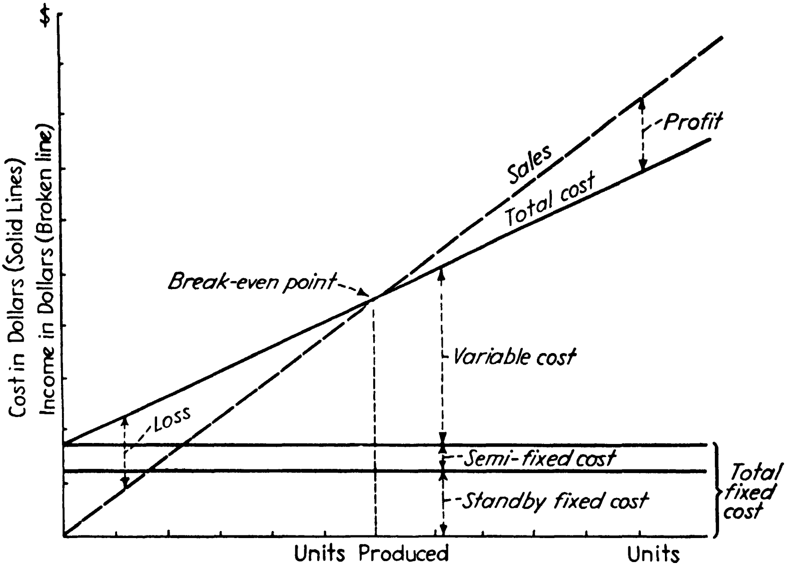



FIG. 13. Simplified chart showing how cost varies with volume of production.

the departmental foremen, the expenses of the servicing and maintenance crews, crane expenses, and inspection costs. These expenses are quite necessary once the decision has been made to operate the plant, but they contribute little directly to the production of the article. The third or *variable* element included in the cost of the article consists of the direct-labor costs, the cost of materials used in manufacturing, and all other items directly dependent upon the volume of production.

The question then arises, what use can be made of the fact that unit costs are affected in seemingly strange and wonderful ways by fluctuations in volume? First of all, it is rather evident that this fact limits the use of the static budget to stable businesses or to those that fluctuate only mildly. In fact, it was the application of the static

budget to the extremely dynamic volume levels of the period following 1929 that led some companies to discard budgets altogether. Those companies that still use the static budget have been forced to recognize changing volume levels by adopting what is known as the *step budget.* The step budget reflects recognition of the effect of volume on unit costs, and requires that the budget be revised periodically as different levels of production are reached.

**The Variable Budget.** However, the real answer to variable costs is the *variable budget.* This type of budget is designed so that it automatically reflects changes in volume. The basis of the variable budget is shown graphically in Fig. 13. This chart is a somewhat simplified diagram showing the method by which total cost can be calculated to any level of production volume. It can be seen that the total cost is composed of three elements: the fixed, semifixed, and variable. The first two elements remain constant (for the purposes of our diagram), whereas the variable element varies proportionately with volume. The three elements when added together at any volume level give the total cost. The total cost in dollars when read from the ordinate (vertical line) and divided by the number of units produced as determined from the abscissa (base line) gives the unit cost at any particular volume level. When the sales volume is superimposed on the chart, it is then possible to ascertain the volume of production that must be maintained at least to "break even" financially on the operations. In addition to showing at which point the business becomes profitable, this chart also shows the amount of profit or loss that may be expected for any specific volume of production.

Let us see how this works. Suppose we are making a product that sells for $1, and we find that the total fixed costs of operating the business per month are $20,000. In addition, we know that the variable cost per unit is $0.80. Suppose, also, we anticipate a sales volume of $70,000 per month. The question is, shall we make a profit at this level of production? A sales volume of $70,000 means that we expect to produce 70,000 units per month, the variable cost for which is 70,000 × $0.80 = $56,000. Add to this the total fixed costs or an over-all cost of $76,000, and it is evident that $6,000 will be lost at this level of production. But if the anticipated sales were to be $120,000 per month, a similar calculation would show that the cost of manufacturing 120,000 units is $116,000, or a profit of $4,000. With costs thus analyzed, it is rather easy to calculate results at any level of operation.

**Limitations of the Variable Budget.** As explained above, the chart (Fig. 13) is a somewhat simplified version of conditions normally encountered. Unfortunately, the cost line of most enterprises is not straight but, rather, is a curve or more probably a series of curves. The semifixed element, for example, may follow no regular line or curve but may be a series of violent fluctuations. Consider for the moment the single semifixed component of a foreman's salary. If only a small volume of business is handled by the company, the department may be small, in which case the foreman will have only a few men under his

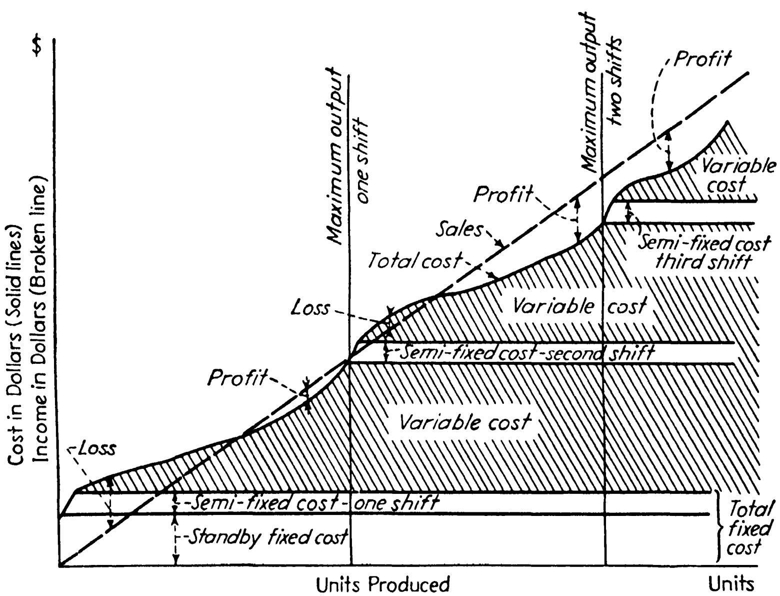



FIG. 14. Typical cost curve showing how cost varies with the volume of production Note the effect (on the cost elements and on the profit) of adding a second and a third shift.

direction. In such an event, he need devote only part of his time to directing his men, and the balance can be spent at productive effort Thus the supervision cost is really only a portion of his salary. But suppose business picks up and more men are added to his department. Then all his time must be given to supervision, and the supervision cost takes a sudden jump as volume is gradually increased. If the volume of business expands further, the foreman's duties may become too great for him to handle, and an assistant will be required at a further increase of supervision cost. Or possibly an additional shift will be necessary, which then doubles that cost.

Or consider the variable cost of operating a business. Unlike the direct cost of operating an automobile involving gas, oil, tires, repairs, etc. (see Fig. 12), the variable costs of operating a business per unit product do not remain constant at all volume levels so as to produce the straight line shown in the simplified chart (Fig. 13). The unit cost of purchased materials, for example, decreases as larger quantities are purchased and better discounts are obtained for quantity buying. Likewise, labor cost per unit varies at different levels of production as different volumes require different methods of manufacture.

As a result of the preceding factors, the typical cost curve of an average concern is more likely to resemble that shown in Fig. 14. Note that although this curve is somewhat more difficult to calculate, once the cost elements have been determined, measured, and plotted, it is still possible to analyze the curve to ascertain how profitable the operations will be.

It is often rather difficult to distinguish between those costs which are classed as variable and those which are semifixed by the decision of management. Sometimes the line drawn between these two elements is rather fine, but nevertheless the distinction is important and must be drawn if the allocation and control of costs are to be achieved.

**Variable Budgets Applied to an Operating Department—A Case Example.** Let us take a simple case example to see exactly how a variable budget may be applied to the operation of a single manufacturing department. Our concern is a small company making a single drop-forged product for use in automotive engines. The production division is under the direction of a plant superintendent, who, with his assistant, is in charge of the several manufacturing departments, the inspection personnel, the receiving, shipping, and stores departments, as well as the toolroom and maintenance men. The items of *overhead expense* attributable to manufacturing operations are as follows:

1. General expenses.
   *a.* Plant superintendent's salary.
   *b.* Assistant superintendent's salary.
   *c.* Toolroom.
   *d.* Maintenance.
   *e.* Final product inspection.
   *f.* Receiving, shipping, stores.
   *g.* Heat, light, power.

*h*. Insurance, taxes, depreciation on plant and equipment.
*i*. General supplies.

2. Expenses attributable to each manufacturing department.
   *a*. Foreman's salary.
   *b*. Wages of assistant foremen.
   *c*. Clerks, sweepers.
   *d*. Supplies.
   *e*. Tools, fixtures, jigs.
   *f*. In-process inspection.
   *g*. Cost of chargeable defective work.

BUDGET—DEPARTMENTAL DATE 8/2/41
DEPT.: M6—Grinding Room FOREMAN: C. Smith
PERIOD STARTING: Aug. 4, 1941 PERIOD ENDING: Aug. 30, 1941
NO. WEEKS PERIOD: 4 NORMAL PRODUCTION CAPACITY: 3,000 units

| Factory account | Acct. No. | 60% | 70% | 80% | 90% | 100% | 110% | 120% |
|---|---|---|---|---|---|---|---|---|
| Foreman | 01 | $ 240 | $ 240 | $ 240 | $ 240 | $ 240 | $ 240 | $ 240 |
| Assistant foremen | 02 | ...... | ...... | 80 | 80 | 160* | 160* | 240* |
| Clerks, sweepers | 03 | 200 | 200 | 400 | 400 | 500* | 500* | 500* |
| Supplies | 04 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| Tools, fixtures | 05 | 100 | 110 | 120 | 130 | 135 | 140 | 145 |
| Departmental inspection | 06 | 200 | 200 | 400 | 400 | 500* | 500* | 500* |
| Defects chargeable | 07 | 180 | 210 | 240 | 270 | 300 | 330 | 360 |
| Total | | $1,040 | $1,100 | $1,640 | $1,700 | $2,035 | $2,090 | $2,225 |

* Includes overtime pay.

FIG. 15.

The general expenses, of course, can be spread or prorated for each department, but since they are under the direct control of the plant superintendent and since each foreman has little if any control over these items, they would logically be placed in the budget of the plant superintendent. The budget prepared for each foreman would then include only those items of expense over which he has direct control and for which he can be charged.

The budget for the grinding department, the foreman of which is Charles Smith, is shown in Fig. 15. Note that the normal or 100 per cent production capacity is at the rate of 3,000 units a month, but that the budget figures are given for various levels of production. The foreman knows in advance just what performance is expected of him, regardless of the degree to which his rate of production may fluctuate during the period. By checking his production each week he is able to calculate at any time just what his performance should be, and

intermediate reports of actual performance at intervals during the period may also be helpful to the foreman in his effort to control his performance. Note that his budget does not prorate to his expenses any items over which he has no control, and thus he can be held directly responsible and answerable for all items in it.

The budget comparison report (Fig. 16) is issued to the foreman immediately after the budgetary period is completed to show him the cost items wherein his costs exceeded the budgeted figure. He is then expected to watch these items closely during the next period or to offer reasons why the budgeted estimates are incorrect and should be raised.

BUDGET COMPARISON REPORT Date 9/2/41

Dept.: M6—Grinding Room Foreman: C. Smith

Period: Aug. 4 to Aug. 30, 1941

Normal Production Capacity: 3,000 units

Actual Production: 2,700 units Percentage Normal Capacity: 90

| Factory account | Acct. No. | Budgeted | Actual | + or − variation |
|---|---|---|---|---|
| Foreman | 01 | $ 240 | $ 240 | $ 00 |
| Assistant foremen | 02 | 80 | 80 | 00 |
| Clerks, sweepers | 03 | 400 | 430 | −30 |
| Supplies | 04 | 180 | 200 | −20 |
| Tools, fixtures | 05 | 130 | 125 | +05 |
| Departmental inspection | 06 | 400 | 360 | +40 |
| Defects chargeable | 07 | 270 | 310 | −40 |
| Total | | $1,700 | $1,745 | $−45 |

Fig. 16.

**Precautions in Budgeting.** Budgeting is only as good as the management that applies it. It can be a very effective means of controlling costs if used properly. It should be used as a standard of performance, not as an inflexible maximum that may never be exceeded.

A new budgetary system may be found to include some rather "wild" estimates. This in itself is not just cause for immediately discarding the system but rather a challenge to estimate more closely for the next period. Generally speaking, the longer the system is in operation, the more accurate the estimates are likely to become.

Although frequently budgeted, direct-labor costs can usually best be controlled through the use of labor-time standards and piecework prices rather than through the medium of budgeting. Budgeting is usually most effective in controlling the overhead or *hidden* costs, as

they are sometimes called. In this connection it is interesting to note that increased mechanization in all industries and in all lines of production has generally increased the percentage of the sales dollar that must be apportioned to cover overhead expenses. Thus it is increasingly important that the overhead components of cost be controlled effectively, and the budget is the best device yet developed to accomplish this control.

A budget is only a *means* for controlling costs and is not an *end* in itself. The keeping of budgetary records creates an expense and hence should be kept to a minimum. Otherwise the cost of record keeping may go so far as to eliminate the savings that would otherwise result therefrom. This means that all needless detail and unnecessary breakdown of cost elements must be eliminated. In fact, a good rule to remember in budgeting is that each record kept should bear the burden of proof that it is necessary to the maintenance of the control desired, and any record that does not satisfactorily establish its need should be promptly discontinued.

### CASE 7

*The Gamma-Beta Foundry and Machine Company.*[1] The Gamma-Beta Foundry and Machine Company makes use of the following account numbers in allocating departmental expenses:

| Acct. No. | Description |
|---|---|
| 1 | Salaries and wages—supervision<br>Superintendents, foremen, and assistants. |
| 2 | Vacation, sick leave, and other lost time<br>Hourly wage employees only. |
| 3 | Salaries and wages—clerical<br>Timekeepers, stenographers, dispatchers, clerks. |
| 4 | Salaries and wages—engineering<br>Labor of engineers employed in plant departments. |
| 5 | Unloading materials and supplies—labor |
| 6 | Pouring iron— labor |
| 7 | Shakeout—labor |
| 8 | Other labor<br>Cranemen, watchmen, gatemen, cleaners, oilers, truckers, laborers, etc. |
| 9 | Departmental losses<br>Cost of material scrapped due to defective workmanship. |
| 10 | Royalties |

[1] Name fictitious.

| Acct. No. | Description |
|---|---|
| 11 | Fuel—coal, gasoline, gas, oil |
| 12 | Sand |
| 13 | Water |
| 14 | Power, light, and heat |
| 15 | Office supplies |
| 16 | Boxing and shipping materials<br>Special supplies such as lumber and nails, which cannot be charged directly to a job. |
| 17 | Supplies<br>Consumable items such as solder, flux, chalk, brooms, paint, lubricating oils, waste rags, gloves, first-aid supplies, and emery cloth. |
| 18 | Maintenance<br>Repairs to building, machines, and other equipment. |
| 19 | Insurance |
| 20 | Taxes |
| 21 | Depreciation |

### Preparatory Question

Segregate the above accounts under the headings:

1. Standby fixed costs.
2. Semifixed costs.
3. Variable costs.

Which of the above accounts should be budgeted against the foreman in charge of each department?

### CASE 8

*Connecticut Salts Company.*[1] The Connecticut Salts Company makes a variety of chemicals, such as chlorine, caustic soda, and chlorates, which are sold to other industrial concerns for use in plating, cleaning, and other in-process operations.

The market-research department of the company prepares quarterly surveys of general business conditions projected a year in advance. This survey is then sent to a top-management *forecasting committee* for review and approval. Once approved, the forecast is used as the basis for a detailed sales-forecast breakdown prepared by the sales department. This breakdown shows units or quantities by quarters for a year in advance, the most immediate quarter showing an analysis by months.

[1] Fictitious name of an actual company.

The sales forecasts next return to the forecasting committee for consolidation into units of production and sales dollars. They are then made available to the cost-accounting department for preparation of the financial budgets, to the division managers for control purposes, and to the production-control department for preparation of manufacturing budgets and for production planning. This last involves a breakdown of the forecasts by plants, and the resultant production schedules translated into raw-material and shipping-container requirements are made available to the purchasing department for advance planning. Actual purchases, however, are made only from plant requisitions supplied at subsequent dates. In similar fashion, manpower requirements are prepared from the production schedules and supplied to the personnel department in each plant.

The various plants send daily production reports to the cost-accounting group, which adds cost figures and prepares monthly reports for comparison with the original budgets. These reports are supplied to top management for control purposes.

## Preparatory Question

Comment on the budgeting system employed by the Connecticut Salts Company, and note any suggestions you have for improving this system.

# CHAPTER VII

# ROUTING OF OPERATIONS AND PROCESSES

Routing as applied to manufacturing is the application of a predetermined, orderly, logical, and economical sequence of operations through which materials, parts, and subassemblies must pass to prepare them during each successive operation for their subsequent development into larger subassemblies or completed products.

Routing is recognized as a major production-control function supplementing, and supplemented by, the other functions of scheduling, dispatching, and follow-up that are so essential to (1) movements of materials, (2) performance of machines, and (3) operations of labor, in transforming materials into manufactured products.

The general routing sequence is primarily determined by the product-development department as it designs the various parts and develops processes for assembling the *sample* or type product prior to its being submitted to the management and to the sales department as an article to be produced.

Since the product-development department's primary interest is to make a product that will have sales appeal, the development of the product may not follow the best routing sequence from the standpoint of manufacturing efficiency. This may be expected, since the routing and processing are only cooperative responsibilities of the product-development department, whereas they are the major responsibilities of the methods department as far as determining them is concerned, and are responsibilities of the production-control scheduling department in scheduling parts or products through the designated processes and operations. Frequently the methods department can suggest minor changes in design that will improve routing and will not alter the effectiveness of the product, but will accomplish the desired results from a methods standpoint.

**Master Route Card.** Upon the adoption of new products or changes in old products recommended by the sales department in conjunction with the manufacturing and financial divisions, it is assumed that customer and/or stock orders will be forthcoming and preparation of master route cards should be started. Their preparation, which is a responsibility of the methods department, is accom-

plished by coordinating the experiences of the product-development and laboratory departments during the development period with the processing department's knowledge and experience gained from other established products, thereby enabling the methods department to determine the ideal routing for the new product. In actual practice it is not always possible to apply this ideal routing because of preferential orders already in process, abnormal volume coupled with delivery commitments, etc. In such cases the necessity of alternative routings becomes apparent. In setting up the ideal routing, therefore, it is usually advantageous to show the second and third choices at the stations where such flexibility exists. It is likewise helpful to note the differential costs of the alternative routings as an aid to the route clerk in deciding the advisability of applying them in relation to other conditions.

The *master route cards*, or *route sheets* as they are sometimes called, are kept in a central file according to products and contain the standard routes through which the component parts of products are to be processed. They are reference records and are not to be consumed for plant processing. The information they contain may be transferred to supplementary forms for plant use in accompanying and identifying work in process. Supplementary forms to be used in this way may be arranged in "sets," a card for each of the various operations through which each part of a product is to be routed. Each card is designed to show the product for which it represents an operation, the particular operation it covers in the process, the time required to perform the operation per piece or per lot, and the succeeding location to which the work is to be moved.

Probably a better understanding of the master route sheet or card and the supplementary route cards will be obtained by citing a specific illustration from the rubber-footwear industry. Rubber shoe parts lists show

1. Gum upper.
2. Gum outsole.
3. Gum inner vamp.
4. Gum foxing.
5. Gum toe cap.
6. Rag filler sole.
7. Rag insole.
8. Rag counter.
9. Cloth heel.
10. Cloth filler.

The master route card for the above shows

1. Gum upper.
   *a.* Compound mixed—Banbury mixer No. 1—Bldg. 216—Floor 1 slabbed and cooled.
   *b.* Compound calendered—self-cutting upper calender No. 2—Bldg. 216—Floor 1.
   *c.* Picked, inspected, booked—calender take-off—Bldg. 216—Floor 4 and racked.
   *d.* Delivered in racks to final assembly—deliver to assembly conveyor—Bldg. 216—Floor 3.
   *e.* Final assembly into shoes.
2. Parts 1–3–4–5 would show the same routing through *a* and *b*, but *c* of No. 1 would become *d* on 3, 4, and 5. Parts 6 to 10, inc., would have some routing identical to and some different from the routings of parts 1 to 5, inc.

By having, in addition to the master route card, sets of operation cards in a master file for each different type of gum shoe, of which each card in the set would be prepared for a different part in the shoe, it is possible for a clerk to withdraw the correct set from the master file for each order to be routed. The information on the cards as filed would be "constant" in that it would be the standard routing for the particular product. When the routing is changed the cards are changed to conform to the new standard routing. The clerk transfers the variable information, which would be the quantity on the order to be routed into the "Quan. this order" space on the operation card. The combination of the constant and *variable* information on a card provides the necessary data as to *what*, *where*, and *how many*, for routing the work. The clerk then sorts the cards, which would comprise one for each part of all products to be routed, into their respective operations. The grand total of the quantities from each card is the amount to be routed to that operation for the orders being routed, which becomes the total per operation. By translating the total into machine capacity, the loading per machine or per operation is accomplished.

Figure 17 is another illustration of the operation card. Note that this card represents operation No. 2, part No. 3 of the route chart shown in Fig. 19. Cards of the same form would be prepared for each operation on the chart.

If the master route sheet or card is to be used without the supplementary sets of operation cards, a transfer of the information from

the master to other supplementary records is necessary to accomplish the objective: to translate all orders into a description of routing or operation stations so that the total exposure in terms of quantities or total time per operation may be determined. The same factoring required to translate the quantities by parts from the orders into time per operation would be necessary as is performed on the individual operation card. As previously stated, an advantage of the card is its use as identification of the work in process after it has been used for the calculating of conversion. A disadvantage of the operation card sets is the need of changing the file sets printed ahead in the event of changes being made in routing and/or standards.

| | Operation Card | | |
|---|---|---|---|
| Product No. M3–160 | | | Shop Order No. 1 |
| | | | Customer order No. 2-164 |
| Oper. No. 2 | Turn and cut off | | or |
| | | | Assembly order No. ____ |
| Part No. 3 | Part name vamp | | |
| Unit lot each | Time/lot 10 min | | |
| Workplace bench No. 4 | Quan. this order 50 | | Total time req'd 500 min |
| Move to oper. 3 | Bldg. same | Floor same | Mach. marking |

FIG. 17. Operation card. This illustrates the type of card set up for each operation of the master set. This card is for part 3 (vamps), operation No. 2 (cut vamps from leather), and move vamps to operation No. 3 (for marking).

**Move Orders.** The need for *move slips* in routing work through the plant is determined to a great extent by the type of production being routed. In repetitive mass production the sequence of operations becomes established and the authority to move a lot of work to the next operation becomes automatic as the truck or container is filled with completed work from an operation. It is a routine sequence that would change only if the operation of one of the stations became impaired, necessitating the temporary adoption of an alternative routing until the original could be restored. In job-order production the routings are usually peculiar to each job; the variable routings require more extensive use of the move slip between stations as authorization and to convey information on the location of the next station to which the work is to be moved. A colored card, to distinguish the move slip from other paper used as work assignments and to attract the attention of the move men, may be used advantageously. It may be included with the work assignment forms for each specific operation

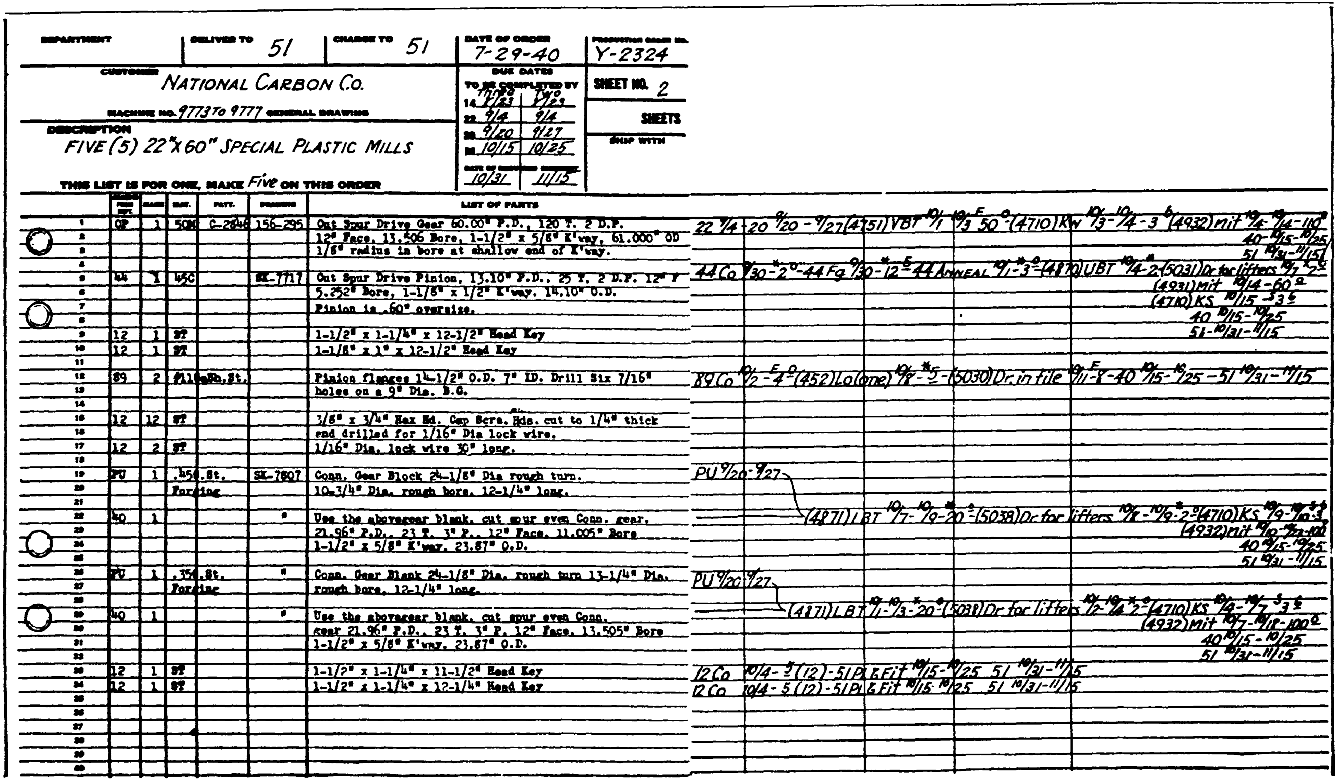
and should show the next station as noted on the bottom of the operation card. An alternative method is to have the colored move card designated to show all operations to be performed, with spaces for checking off the completion of each job. In this case the card would accompany the work throughout the routing. In either case the card should be concealed until the work is completed at each operation and then displayed prominently as a signal to the move men that the work is completed and ready for movement to the next operation.

**Effects of Plant Design on Routing.** Routing may be considered in two major subdivisions: (1) either the sequence has been predetermined so that buildings and internal layouts have been designed to fit the products to be manufactured, or (2) existing buildings and equipment are converted and rearranged to accommodate products to be processed. It is presumed that the greater application of the routing function concerns the latter, since in the present competitive era changes in existing products are generally more frequent than the setting up for production of entirely new products. Products seldom enjoy an indefinite period of maximum production without change. Consequently the necessity for revising routings constitutes a continuous need for studying, preparing, and making effective the most economical course or route that materials, parts, and subassemblies are to follow through the plant.

Maintenance of routing procedure through a plant designed and built for the products is obviously a simple matter, but maintenance of the best routing for varied products in the converted facilities of a plant may be recognized advantageously as an ever-present problem that will justify periodic checking and rechecking from an efficiency standpoint.

**Effect of Type of Manufacture on Routing.** Products are manufactured from materials, parts, and subassemblies, which may be processed within the plant, purchased from vendors, procured on subcontract from other manufacturers, or a combination of the three. The different sources of components present different routing problems, but in any case they must be coordinated so that the necessary parts will meet the process at the proper assembly junction if shortages, delays, and abnormal banks are to be averted. The importance of these objectives is obvious.

**Basic Data for Routing.** The logical approach to the routing function is an analysis both of the component parts of the products (*parts list*) and of the production schedule of "how many" and "when" in units, lots, hours, shifts, days, or weeks. From the economy stand-



Department | Deliver to 51 | Charge to 51 | Date of order 7-29-40 | Production order no. Y-2324

Customer: NATIONAL CARBON CO.

Machine no. 9773 to 9777 General drawing

Description: FIVE (5) 22"X60" SPECIAL PLASTIC MILLS

This list is for one, make Five on this order

| Due dates | To be completed by: Three | Two |
|---|---|---|
| 14 | 8/23 | 8/23 |
| 22 | 9/4 | 9/4 |
| 30 | 9/20 | 9/27 |
| [illegible] | 10/15 | 10/25 |
| Date of required shipment | 10/31 | 11/15 |

Sheet No. 2 | Sheets | Ship with

| Line | Order from dept. | Make | Mat. | Patt. | Drawing | List of parts | Routing |
|---|---|---|---|---|---|---|---|
| 1 | CP | 1 | 50M | C-2848 | 156-295 | Cut Spur Drive Gear 60.00" P.D., 120 T. 2 D.P. | 22 9/4-20 9/20-9/27 (4751) VBT 10/1 10/3 50-(4710) Kw 10/3-10/4-3 (4932) mit 10/4-10/14-110 |
| 2 | | | | | | 12" Face, 13.506 Bore, 1-1/2" x 5/8" K'way, 61.000" OD | 40-10/15-10/25 |
| 3 | | | | | | 1/8" radius in bore at shallow end of K'way. | 51 10/31-11/15 |
| 4 | | | | | | | |
| 5 | 44 | 1 | 45C | | SK-7717 | Cut Spur Drive Pinion, 13.10" P.D., 25 T. 2 D.P. 12" F | 44 Co 9/30-2-44 Fg 9/30-12-44 Anneal 10/1-3-(4870) UBT 10/4-2-(5031) Dr for lifters 10/7-2 |
| 6 | | | | | | 5.252" Bore, 1-1/8" x 1/2" K'way. 14.10" O.D. | (4931) mit 10/14-60 |
| 7 | | | | | | Pinion is .60" oversize. | (4710) KS 10/15-3 |
| 8 | | | | | | | 40 10/15-10/25 |
| 9 | 12 | 1 | ST | | | 1-1/2" x 1-1/4" x 12-1/2" Head Key | 51-10/31-11/15 |
| 10 | 12 | 1 | ST | | | 1-1/8" x 1" x 12-1/2" Head Key | |
| 11 | | | | | | | |
| 12 | 89 | 2 | #1108Sh.St. | | | Pinion flanges 14-1/2" O.D. 7" ID. Drill Six 7/16" | 89 Co 10/2-4-(452) Lo (one) 10/8-5-(5030) Dr. in file 10/11-8-40 10/15-10/25-51 10/31-11/15 |
| 13 | | | | | | holes on a 9" Dia. B.C. | |
| 14 | | | | | | | |
| 15 | 12 | 12 | ST | | | 3/8" x 3/4" Hex Hd. Cap Scrs. Hds. cut to 1/4" thick | |
| 16 | | | | | | and drilled for 1/16" Dia lock wire. | |
| 17 | 12 | 2 | ST | | | 1/16" Dia. lock wire 30" long. | |
| 18 | | | | | | | |
| 19 | PU | 1 | .45C.St. | | SK-7807 | Conn. Gear Block 24-1/8" Dia rough turn. | PU 9/20-9/27 |
| 20 | | | Forging | | | 10-3/4" Dia. rough bore. 12-1/4" long. | |
| 21 | | | | | | | |
| 22 | 40 | 1 | | | " | Use the abovegear blank, cut spur even Conn. gear. | (4871) LBT 10/7-10/9-20-(5038) Dr for lifters 10/8-10/9-2-(4710) KS 10/9-10/10-3 |
| 23 | | | | | | 21.96" P.D., 23 T. 3" P., 12" Face, 11.005" Bore | (4932) mit 10/10-10/23-100 |
| 24 | | | | | | 1-1/2" x 5/8" K'way, 23.87" O.D. | 40 10/15-10/25 |
| 25 | | | | | | | 51 10/31-11/15 |
| 26 | PU | 1 | .35C.St. | | " | Conn. Gear Blank 24-1/8" Dia. rough turn 13-1/4" Dia. | PU 9/20-9/27 |
| 27 | | | Forging | | | rough bore, 12-1/4" long. | |
| 28 | | | | | | | |
| 29 | 40 | 1 | | | " | Use the abovegear blank, cut spur even Conn. | (4871) LBT 10/1-10/3-20-(5038) Dr for lifters 10/2-10/4-2-(4710) KS 10/4-10/7-3 |
| 30 | | | | | | gear 21.96" P.D., 23 T. 3" P. 12" Face, 13.505" Bore | (4932) Mit 10/7-10/18-100 |
| 31 | | | | | | 1-1/2" x 5/8" K'way, 23.87" O.D. | 40 10/15-10/25 |
| 32 | | | | | | | 51 10/31-11/15 |
| 33 | 12 | 1 | ST | | | 1-1/2" x 1-1/4" x 11-1/2" Head Key | 12 Co 10/4-5 (12)-51 Pl & Fit 10/15-10/25 51 10/31-11/15 |
| 34 | 12 | 1 | ST | | | 1-1/2" x 1-1/4" x 12-1/4" Head Key | 12 Co 10/4-5 (12)-51 Pl & Fit 10/15-10/25 51 10/31-11/15 |
| 35 | | | | | | | |
| 36 | | | | | | | |
| 37 | | | | | | | |
| 38 | | | | | | | |
| 39 | | | | | | | |
| 40 | | | | | | | |

FIG. 18. Combination parts list and routing sheet.

point, the smaller time increments of hours or shifts are more desirable for efficient space utilization and for quick turnover advantages. These are determined to a great extent by the capacity of tote boxes, skids, and other limitations on containers used for storing and moving in-process parts.

The important variable to be determined for routing each product is the "size of lot" in which it is going to be put through the plant, *i.e.*, are the products to be put through one at a time (unit), or by the dozen, the hundred, or in gross lots. Quite frequently the size of the container used for handling the parts between operations determines the lot size. There are instances where the weight may be more important than the dimensional area. There may also be limitations on the number that can be processed within a certain period of time to permit necessary turnover between operations. In general, the size of a lot should not require that it be tied up at any operation more than one shift, if minimum banks between operations and maximum turnover are to be realized.

The parts-list analysis will break down the processing requirements of each component in terms of machining by types of machine, such as hand cutting, stamping, drying, aging, shrinking, curing, and other peculiarities of the part in the sequence of their application. The production schedule will provide the quantities and extent of both; processing requirements and quantities will determine the volume exposure for which provision must be made on the available facilities. Delivery commitments will determine whether the total volume may be processed consecutively or whether interruptions for parts of other orders to be processed through the same facilities on which commitments have been made may be advisable. It is important to keep in mind the total available facilities of the particular process or operation. The objective is to route the work through them so expeditiously that "idle time" of facilities will be eliminated. A more detailed explanation of this phase of the routing function, which relates to scheduling and dispatching, is given in Chaps. VIII and IX.

**Controlled Banks.** One of the secrets of effective routing procedures is to allow tolerances in the form of controlled banks at work stations. The principle of operation with controlled banks is to route the jobs requiring minor machine changes in sequence and schedule the quantities so that some of the next job will be at the station when 50 to 75 per cent of the present job should be completed. The exact amount of the overlap (or bank) can be determined by the product and conditions experienced on the job. Obviously the amount

determined as advisable should not occupy space that will interfere with the normal flow or handling of the job. Operation banks thus controlled provide a form of insurance against lost machine time and transfer of workers to other jobs, which are ordinarily the alternatives when things happen that interrupt the normal flow of work as routed. It can readily be understood that controlled banks have their greatest application in the routing of small products or parts on a mass-production basis. Despite the skill and care exercised in the establishment of operation standards, there are usually fluctuations that can best be covered by providing for a little overlap of parts in the sequential order of jobs to ensure that there will always be the next job to shift to in the event of unexpected trouble or earlier completion.

Another very important supplement to the routing procedure is the effectiveness of the expediting or follow-up service designed to keep work moving and to reroute in the event of necessity. Mere mention of the importance of this phase is sufficient at this point, as more complete coverage will be made at the appropriate place in Chap. X on Follow-up.

**Conveyorized Routing.** Assembly routing as used in automobile manufacturing consists of auxiliary routings of parts or subassemblies into a main line or conveyor route. The product, in this case an automobile, is attached to and moves with the conveyor over a definite course. In progressing over the route, the chassis frame has built upon it at various subsequent stations or junctions the parts or subassemblies that have been routed to meet the main assembly conveyor in the sequence in which they are to be affixed, until the completed product is removed at the other end of the conveyor. It is apparent that numerous detailed side-line routings of materials, parts, and subassemblies are necessary, either in other sections of the plant or in subcontracted plants to make possible the major assembly routing as carried out on the assembly conveyors.

It should be apparent from the foregoing illustration that the entire manufacturing process is a composite of minor and major routings. Raw materials are routed through various operations and processes to transform them into the processed stocks of the specific industry. Processed stocks are cut into shapes, formed, and prepared as parts for subsequent operations through another series of routed operations. Parts are routed either from stores, between plants, or within the plant, through various operations into subassemblies. Subassemblies are routed to larger assemblies and final assemblies

into finished products that very often require postassembly routings through painting, curing, or lacquering processes before they are shipped as consumer merchandise into markets.

### CASE 9. ROUTING

*Long Last Shoe Company.*[1] The Long Last Shoe Company, an old and well-established Massachusetts concern that has for the last eighty years occupied the same three-story mill-type building, is well known for its fine-quality men's shoes. Raw materials consisting primarily of leather of various grades and cloth fabric required in shoe construction are received on the first floor of the building. The material used for the upper part of the shoe is taken by elevator to the second floor, where it is temporarily stored until required for processing in the fitting room located on that floor. Leather for the soles and heels is taken to the top floor to the making room, where it is processed, and there also the finished uppers from the fitting room and the soles are matched, formed, and polished into the finished shoe.

The greater part of the shoe dollar is spent in the fitting room, and the workmanship in this room, together with the quality of materials used, accounts for the difference between the high- and low-grade shoe, and it is in this all-important fitting process that the Long Last Shoe Company is encountering a breakdown in its production control.

Essentially, the fitting process consists of forming the shoe upper by cutting out both leather and fabric parts and stitching them together to form the part of the shoe above the welt. Three main parts go into the manufacture of the upper. They are (1) the *vamp*, which is the toe and that part of the shoe above the sole and welt and in front of the ankle seam; (2) the *top*, or that part of the upper to the rear of the ankle seam; and (3) the *linings* for both tops and vamps.

The routing of the material during this fitting process is shown in Fig. 19, which is a somewhat simplified version of that used by the company in that only the most important operations are shown. The leather hides, rolled up in bundles, are inspected on benches assigned to the cutters. The cutters first read the cutting instructions that have been inserted in the bundle. They then select the proper patterns from near-by pattern storage racks to correspond with the type and style of shoe it is desired to make. The cutting operation

[1] Name fictitious.

on leather consists of placing the hide on the cutting bench, placing a tin pattern on the hide, and cutting the leather with a sharp knife.

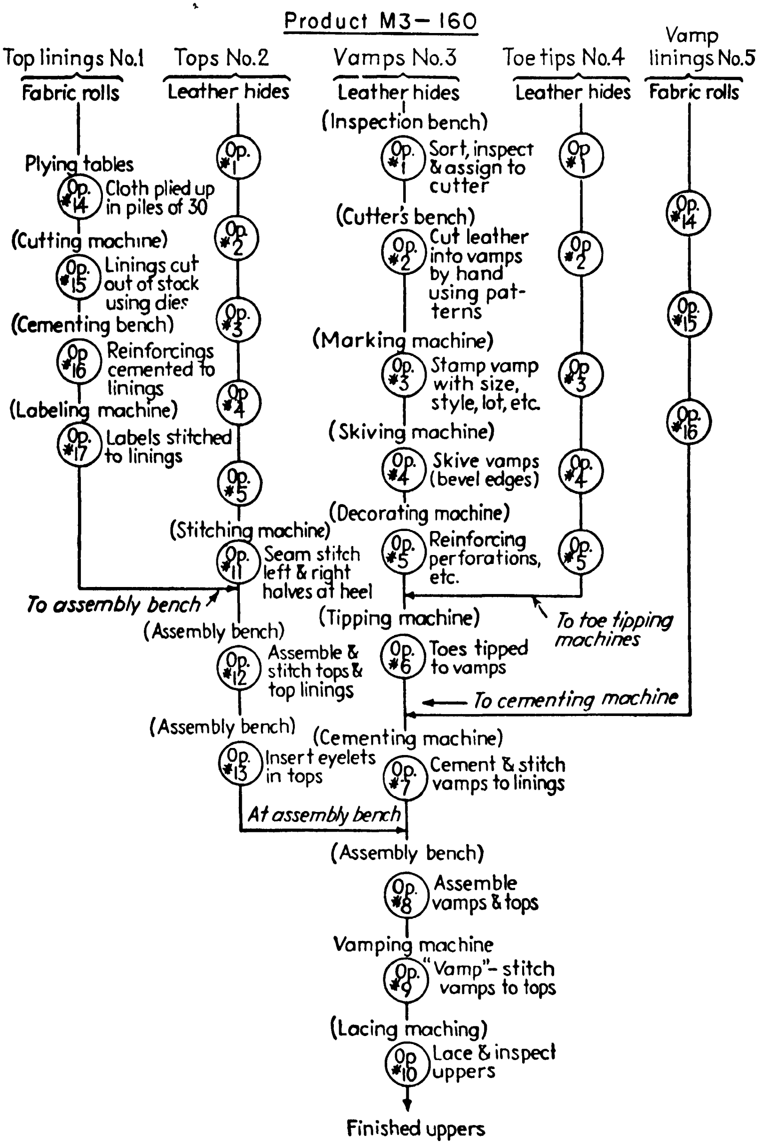


Fig. 19.

Operation 14 consists of taking the fabric that is received in rolls, piling it up in layers or plies by folding it back and forth, and cutting

the folds at each end, resulting in a pile of laminated stock from which the individual cuts are made.

Operation 15 is called *clicker cutting* and consists of placing the cloth in the cutting machine or "clicker" and die-cutting through 30 layers or plies at each stroke of the machine.

The breakdown in production control occurs at the point of assembly. As can be seen from the route chart, the lots of vamps, tops, and linings all finally meet at the assembly bench, at Operation 8 are assembled, and at Operation 9 the parts that go to make each upper are vamped (stitched together). Because of the large number of types and sizes of shoes made, it is very difficult to get these three parts for a lot of shoes of a particular size and style to arrive simultaneously at the assembly bench. The oxford shoe requires on the average about 40 different operations in its manufacture, but this may vary between 20 and 60, depending on the style and the decorative features required by the style. Wing-tip shoes, for example, require more operations than those with plain toes. Thus the vamps on a lot of wing-tip shoes are often slowed up, and the tops and linings arrive at the point of final assembly before the vamps. This holds up completion of the shoe and also contributes to an acute storage problem at that point. On other types of shoes the tops may be delayed in processing, with a subsequent tying up of vamps and linings at the assembly point. Consequently the present routing calls for storing each lot of vamps, tops, and linings in separate bins at the assembly point until all the parts for a particular lot have arrived, at which time all the parts are released for assembly. However, long delays are often occasioned by missing parts, and shortages frequently crop up with a subsequent breakdown of control at that point.

At present the parts of the shoe are moved about the second floor in boxes on casters that the workers themselves push from one operation to the next. The wheeling of these conveyances about the room often interferes with the work of other workers, and furthermore, when they get the boxes to their workplace, the workers must bend over, pick up a handful of parts, and place them on their machines or benches.

The management of the concern recognizes that the procedure outlined in the preceding paragraphs is not entirely in keeping with modern methods of production control. Although there are located about the room several machines of each type required and the machines of any one type are interchangeable and are capable of doing the work of any of the others of that type, the management knows

from past experience that with their high-quality and hence rather low-volume production scattered over many different styles it would be far from economical to set up a separate production line for each style. Nevertheless, the management feels that a way can be found to improve the method of conveying work, if necessary, rearranging the machines and incorporating the changes into a system for synchronizing the arrival of the parts for assembly so as to eliminate holdup and delays from that point on.

### Preparatory Question

Advise the Long Last Shoe Company as to steps it might take to improve the production control of its fitting room, and draw a route chart (using the same operation numbers and omitting the description, if you wish) that would result under your proposed system.

# CHAPTER VIII
# SCHEDULING PRODUCTION

Scheduling is the function of production control that coordinates the routing and dispatching functions by allocating quantities of materials, parts, and products into processing facilities of the plant at specified times. It covers the how many and when portions of the manufacturing cycle. The determination of how many to be produced is usually developed from the sales department forecasts of the quantities it expects to be able to sell (covered in Chap. III). This may comprise actual business on the books in both job-order and mass-production plants as of the forecast date, plus an estimate of additional volume, or may be completely estimated for the period of the forecast. The latter has greater application in mass-production plants. The sales department has its own procedures for compiling the forecasts of all sales outlets, which likewise have procedures for canvassing the sales fields through their contacts in the territories they cover.

The sales forecast submitted in both job-order and mass-production plants is subject to change by the management committee,[1] made up of top-management sales, manufacturing, and financial personnel of the company. Such a committee may

1. Decide that the forecast is too conservative and increase the estimate, with the objective of better use of plant facilities and setting a higher goal to be sold.
2. Determine that the forecast is too ambitious, on the grounds that plant facilities will have to be enlarged to produce the quantities, or that it will require additional personnel or excessive overtime work, the increased cost of which will not justify the increased volume.

**Master Schedules.** After the decisions have been made on forecasted volume and on the approximate periods during which certain rates of production will be needed to meet sales requirements, the two main factors for the preparation of the master schedule are available. The master schedule is a predetermined-range forecast that consolidates into a coordinated plan the sales estimate, the inventory position, and

[1] As described in "Production Control through Control of Materials," by Walter A. Sharritts and LeRoy M. Hanford of the Carrier Corp., A.M.A. No. 173.

the production required for each commodity to be manufactured during the period covered by the schedule.

Numerous subdivisions of the master schedule are possible and advisable in many cases:

1. The sales forecast may be split into the outlets through which sales are to be made. These show the portions of the total to be sold by chain stores, wholesale accounts, branches, and export outlets.

Date June 12, 1941 Copies to:

MASTER SCHEDULE CHART

UNIT CASES

PRODUCT________________ PERIOD: Actual through April forecast balance, 1941

AV. UNIT VALUE $30 per case

| Past record | Days/wk. | Days/yr. | Daily rate | Total prod. | | Total sales | | Average inventory | | Turn-over |
|---|---|---|---|---|---|---|---|---|---|---|
| 1932 | | 244 5 | 193 | 48,385 | | 49,955 | | 11,367 | | 2 71 |
| 1933 | | 201 | 217 | 43,610 | | 39,399 | | 11,427 | | 3.06 |
| 1934 | | 229 | 235 | 53,746 | | 52,671 | | 11,477 | | 4 10 |
| 1935 | | 248 | 289 | 71,706 | | 64,981 | | 16,410 | | 4.08 |
| 1936 | | 248 | 314 | 78,019 | | 74,323 | | 17,149 | | 3.06 |
| 1937 | | 231 | 448 | 103,374 | | 87,402 | | 32,441 | | 3.69 |
| 1938 | | 180 | 283 | 50,880 | | 60,918 | | 19,307 | | 2 07 |
| 1939 | | 225 | 337 | 75,660 | | 71,595 | | 22,060 | | 3 08 |
| 1940 | | 234 | 345 | 80,528 | | 83,312 | | 23,648 | | 3 53 |
| 1941 | | Days/Mo. | | | | | | | | |
| Jan. actual | 5 | 24 | 424 | 10,137 | | 13,246 | | 14,152 | | |
| Feb. actual | 5 | 22 | 455 | 9,997 | | 7,141 | | 16,735 | | |
| Mar. actual | 5 | 23 | 453 | 13,407 | | 8,152 | | 18,816 | | |
| Apr. actual | 5 | 24 | 460 | 11,899 | | 8,089 | | 22,359 | | |
| May forecast | 5 | 21 | 475 | 9,991 | | 6,275 | | 26,075 | | |
| June forecast | 5 | 21 | 490 | 10,300 | | 8,050 | | 27,900 | | |
| July forecast | 5 | 13 | 490 | 6,350 | | 9,825 | | 24,425 | | |
| Aug. forecast | 5 | 21 | 490 | 10,300 | | 12,050 | | 22,675 | | |
| Sept. forecast | 5 | 21 | 490 | 10,300 | | 11,450 | | 20,825 | | |
| Oct. forecast | 5 | 23 | 390 | 9,000 | | 9,200 | | 20,625 | | |
| Nov. forecast | 5 | 19 | 315 | 6,000 | | 8,400 | | 18,225 | | |
| Dec. forecast | 5 | 21 | 315 | 6,625 | | 6,850 | | 17,300 | | |
| Totals and averages | | 253 | 441 | 111,306 | | 108,728 | | 20,843 | | 5.20 |

NOTE: Totals are slide-rule calculations and are not arithmetically accurate.

FIG. 20.

2. Production requirements may show annual totals subdivided into months, days per week, and daily rates to be scheduled to produce the necessary volume. The object is to prepare the master schedule with as much accuracy as possible, but it usually works out that the immediately succeeding period is fairly reliable, with the subsequent periods becoming less dependable as the complete schedule is developed.

Master schedules are prepared for various periods of time, but for short-cycle products a good practical period is a year divided into quarters that are subdivided into months and/or weeks. With a sales forecast submitted, for example in October or November, for each month of the following calendar year, it is possible to plan production for that same period. *Lead time*, when used in connection with master schedules, is the time between completion of production and delivery to markets. It naturally varies with different products and the correct amount must be determined according to conditions.

Adjustable schedules have been proved by experience to be most advantageous in taking care of the fluctuations that occur during any predetermined schedule. Fluctuations result from unpredictable conditions encountered in the sales field and from conditions of absenteeism, machine breakdowns, material delays, and labor variations in the manufacturing process. Therefore, provision for periodic revisions of the schedule is very desirable. The master schedule illustrated in Fig. 20 provides this flexibility and has proved its practicability. It will be noted that the months listed are shown as *actual* and *forecast*. The schedule is reissued monthly, and as each reissue shows the actual accomplishment of the preceding month it automatically displaces it as a *forecast month*. The entries against the *actual months* show the performance attained, and the remaining forecasted months are revised according to the adjustments necessitated by changes that have occurred in the sales and production experiences.

**The Common-denominator Theory of Schedule Variation.** The ideal master schedule from a production-control standpoint is one that forecasts accurately by specific items the quantities to be produced daily for the maximum number of days. Seldom is the ideal schedule realized in actual practice, for sales forecasts and production returns from planned shop programs usually fluctuate. Furthermore, manufactured lines of products forecasted in the same plant master schedule carry variations that affect the shop orders prepared from it. The master schedule illustrated in Fig. 20 is for a general classification of product such as men's shoes. It is impossible to forecast accurately the percentages of the totals that will be required in the various shades or what percentages will be work shoes and dress shoes, whether they will be of the high or low variety and of bal- or blucher-cut construction. As the actual scheduling of orders into production according to the forecasted rates becomes effective, the specific types to be scheduled must be determined. It is at this point that processing variations

in types must receive consideration. These variations usually affect the personnel and processing facilities and result in greater or lesser quantities being produced in the same unit of time.

This situation makes apparent the need for determining a common denominator in scheduling plant production from this type of master schedule. The common denominator used here is one of the products, adopted as average from a plant-processing-requirements standpoint, the other products being similarly graded, with variations upward or downward from the average. Thus, if product *C* were established as the average, *A* might be 0.7 *C*; *B* might be 0.9 *C*; *D*, 1.5 *C*; *E*, 2 *C*; etc.

This procedure makes possible an evaluation of the complete production forecast in terms of *C* products and has proved most helpful in translating master schedules for production planning. The scientific solution of the common-denominator theory, in plants set up on standard hours of labor for internal processing, is to translate all the production requirements into standard hours, adjust for efficiency experience, and proceed with production planning on the standard-hour basis. The standard-hour theory presumes standard-time allowances to perform each operation of every product being scheduled. Thus, in the master schedule for men's shoes, when subdivided into high, low, and bal- and blucher-cut varieties for actual scheduling into process operations, each different shoe would have a set of standard-time allowances for each operation covering its entire process. By translating the quantities on the orders to be scheduled into their equivalent time requirements, the common denominator is *time.* Since machine capacities are likewise reckoned in pieces per unit of time, the problem of determining operation or plant facilities in terms of production through the medium of time becomes a simple matter. The available machine or operation capacity in the plant—which, for example, is assumed to be eight hours per day—may be utilized by having all of one kind or various combinations of several kinds of products scheduled to it, so long as the total of the various kinds does not exceed the eight hours available. An illustration of this phase might be

| | |
|---|---|
| 200 pairs of *A* style representing | 1.4 hours of capacity |
| 300 pairs of *B* style representing | 2.7 hours of capacity |
| 390 pairs of *C* style representing | 3.9 hours of capacity |
| 890 pairs of combined styles representing | 8 hours of capacity |

Thus it becomes apparent that production planning for effective scheduling, which means adequate quantities at specified times, requires

more than relaying a sales forecast to the manufacturing facilities of the plant.

**Allowance for Rejections.** The master schedule being developed from sales forecasts assumes the quantities for salable products. This introduces the necessity for overproduction to cover rejects. Provision in shop schedules must be made for reject allowances and must be based on experience, since there is no known way of accurately predetermining them.

**Determining the "When" of Scheduling.** The data used for determining the dates for the production of a given product or standard part are procured from (1) the production forecasting described in Chap. III, or (2) the delivery specifications of the customer in case of production for customer's order, or (3) the minimum time in which the order can be produced. The requirements of these factors, however, may be altered by general internal conditions, including (1) availability of equipment and processing facilities, (2) availability of personnel skilled in the production-operation requirements of the product, and (3) availability of parts and materials.

Under normal conditions of operation, long-term planning will have provided for equipment, materials, and personnel sufficient for production to meet anticipated demands. Difficulties arising from special orders or unexpected variations in demand for particular products are conditions that have emphasized the importance of an organized procedure through which the production time of a plant may be scheduled to maximum efficiency. Recognizing that these difficulties are inevitable, management has sought means for facilitating an even flow of production that will eliminate waste in machine- and man-hours, at the same time providing for the completion of products within the delivery specifications of the customer.

**Translating Product Orders into Component Parts for Processing.** When the necessary adjustments to meet all known conditions have been made and the total quantities to be produced have been determined, then scheduling becomes a problem of further subdividing the products. This consists of breaking down the products to be produced within specified periods into the component parts required for their assembly. The components probably will include purchased parts from outside vendors, parts and subassemblies to be processed within the plant, and possibly some of both to be procured on a subcontract basis. Plant-production scheduling must coordinate all the parts and subassemblies for final-assembly scheduling, but requires a more de-

tailed job in scheduling materials and parts that are fabricated within the plant in preparation for the final assembly.[1]

**Shop Orders.** In a certain sense shop orders may be considered as the secondary schedules in manufacturing, in that they are determined from the primary master schedules of the plant. The "secondary" reference is not to be interpreted as any reflection on their importance since, on the contrary, they are the really important part of the scheduling function in accomplishing the objectives set forth in the master schedule. Manufacturing, as emphasized in preceding chapters, is a building process by which the materials, parts, and subassemblies from extractive and other manufacturing industries are given new form by the application of machines, tools, and labor. In order to apply the proper machines, tools, and labor to these materials, parts, and subassemblies, it is necessary to break down the ultimate products to be produced into their component parts and translate these parts into basic materials and the processing required to transform them. It is upon this basic foundation that the parts of products are ultimately joined together as are the cement blocks or stones of a structural foundation. The preparation of the parts may very logically start with a requisition on stores to deliver a predetermined number of yards, pounds, or gallons of raw material to a certain machine or location at a designated time. Simultaneously another order to the same machine or operation will authorize the application of certain tools and hours of labor upon the material to prepare it for subsequent operations. By a series of such authorizations or shop orders at specified times the material is transformed into parts and subassemblies. These parts and subassemblies may be subsequently scheduled, with other purchased or subcontracted parts, through the media of other shop orders, to be joined in final assembly to form the products indicated by the master schedule. The scheduling to the processing and subassembly stations is done in conjunction with the routing function described in Chap. VII. Routing, as explained, indicates which operations and stations, according to predetermined sequence, are required to transform the materials, parts, and subassemblies into products. Scheduling determines the specific parts and how many of them are to be at the stations of operation at certain definite times—in other words, "when."

[1] The scheduling of the subcontracted parts probably necessitates an equally detailed scheduling procedure for the similar organization in the subcontract plant, and there is no intention here of creating the impression that the easier scheduling jobs are always subcontracted.

The details contained in shop orders vary with the plant and the products. They may be a consolidation of several identical parts from numerous stock and customers' orders, or they may be for a specific stock, customer, or job order. The basic principle to be followed in any case is maximum productive time with minimum interruptions for setups and changes. From this standpoint it is obvious that the scheduling officer should attempt to schedule the complete exposure, either by consolidation of all orders into one large shop order, or in a sequence that will permit the performance of the identical operations from different orders without setup changes. The limiting factor in the accomplishment of this objective is *time*. Delivery requests or commitments may be such that the desired volume completion would require so much time that interruptions for setup changes will have to be allowed to complete designated orders on schedule. The ideal situation from an economical manufacturing standpoint is to set up an operation or a machine and run all of the production required from that particular setup without changing it, even to the extent of completing that particular operation on orders that do not require delivery until months later. Obviously there are other orders to be delivered in the interim requiring a different setup of the same machine, orders that would be held up if this arrangement were in force. Consequently the ideal can only be accomplished within the limitations of delivery commitments.

This particular phase of scheduling efficiency is usually more difficult to accomplish in job-order production. A possible exception may be when the products of the job-order shop have a sufficient number of identical parts to justify their being combined into volume production for stores. They will subsequently be withdrawn for assembly. If this exception is impossible and the alternative, as is usually the case in job-order manufacturing, applies, it is obvious that the extent to which sizable volume can be realized will depend almost entirely upon the volume contained in the individual orders being scheduled.

In the scheduling of several component parts of a job-order assembly, each with a different process time, each part is theoretically scheduled so that it will be completed immediately prior to its being required for assembly. In practice, owing to the limitations of equipment, personnel, and materials, it is seldom possible to complete all parts at the same time. Breakdowns, excessive rejections, preferentials, and inaccuracy of estimates creep in. Also, certain standardized parts are made more economically if manufactured, not in small lots

to a particular order, but rather in large lots manufactured in advance to stock. Thus storage facilities must be provided for parts that are being held pending the arrival of those not yet completed. This involves the storage of in-process material referred to in Chap. XI.

**Importance of Sequence Scheduling.** In some industries, order or sequence in scheduling is a consideration equal in importance to the "how many" and "when." In the chemical industries and in rubber and plastic mills where processes require the use of very expensive mixing facilities for various types of materials, the sequence is most important. Usually the batches to be processed are of different composition and vary greatly in regard to color, texture, and contamination characteristics. It is usually possible to grade them according to their pecularities and minimize the contamination hazard by scheduling according to a predetermined sequence in which those stocks of minor variation are processed successively. In the cases of temperature variations among stocks, considerable processing time may be saved by scheduling minimum-temperature-requirement stocks first on a shift when equipment is cold and following them with higher-temperature-requirement stocks, so that those of highest-temperature requirement are scheduled at the end of the shift. Thus wasted time for cooling can be eliminated.

**Progress and Control Charts.** It is too much to expect that if one applies the best scheduling technique to the job everything will happen as planned. It is necessary that follow-up procedures be applied along the route and that a record be maintained of the progress of work as planned. The items of progress on schedule logically comprise the fundamentals upon which the scheduling is based, namely, actual quantities of certain materials, parts, and subassemblies at routed locations in the process at the proper time, shown as compared to the previous planning. The Gantt chart may be ideally adapted to show all of the desired information and may be designed and used advantageously for practically all conditions.

The underlying principle of Gantt chart design is to show graphically for quick analysis and decision both the objectives and the progress made in attaining them. Obviously the size of spaces, units, and time increments to be used will depend upon the purposes to be served and must therefore be left to the discretion of the designer. An illustration of a daily schedule chart applied to a vamp-cutting operation in the manufacture of shoes is shown in Fig. 21. Each hour of the eight-hour shift is subdivided into five sections having a part (vamp) value of 25. The extended hourly schedule would represent

five times 25, or 125 scheduled each hour to cut the 1,000 per day or eight-hour shift.

The *actual* line may be extended periodically throughout the day according to the actual quantity cut at each period and will show the progress being made against the schedule.

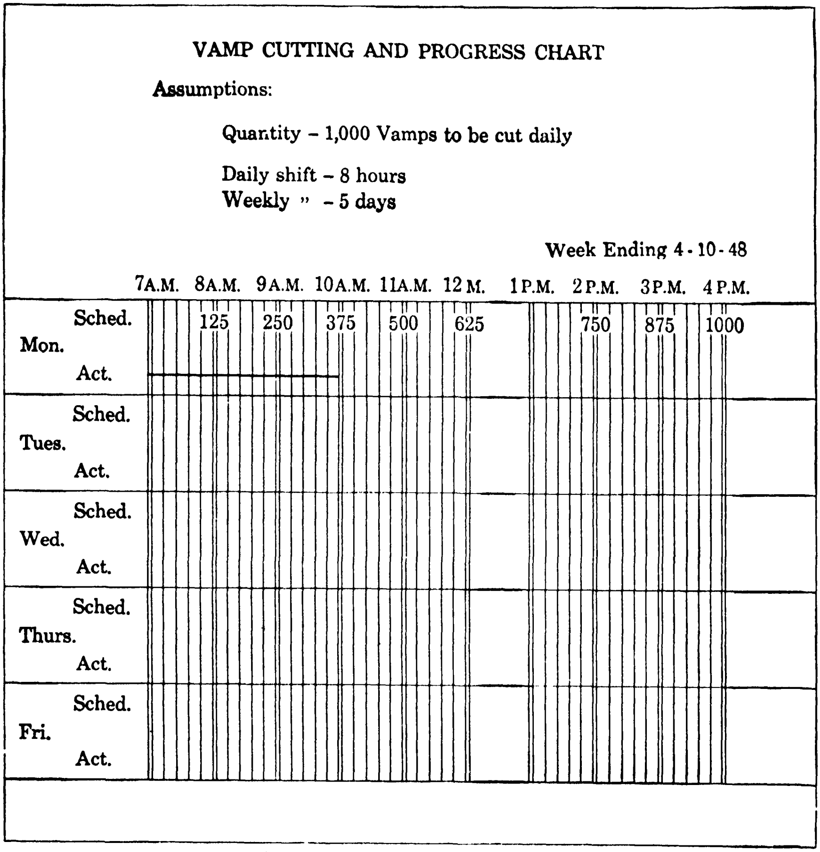



FIG. 21. Daily schedule chart.

Figure 22 is another example of the use of the Gantt chart. Taking the first item, the top platen, we note that the engineering design on this part is scheduled for completion on Jan. 21. The casting is purchased and should be received on Feb. 11. The first operation, which is planning (PL), is scheduled for completion Feb. 25; it then passes to subsequent operations of vertical boring (VBO), horizontal boring (HBO), etc., as shown on the chart, and is to be completely machined ready to go to the erecting shop on Apr. 8.

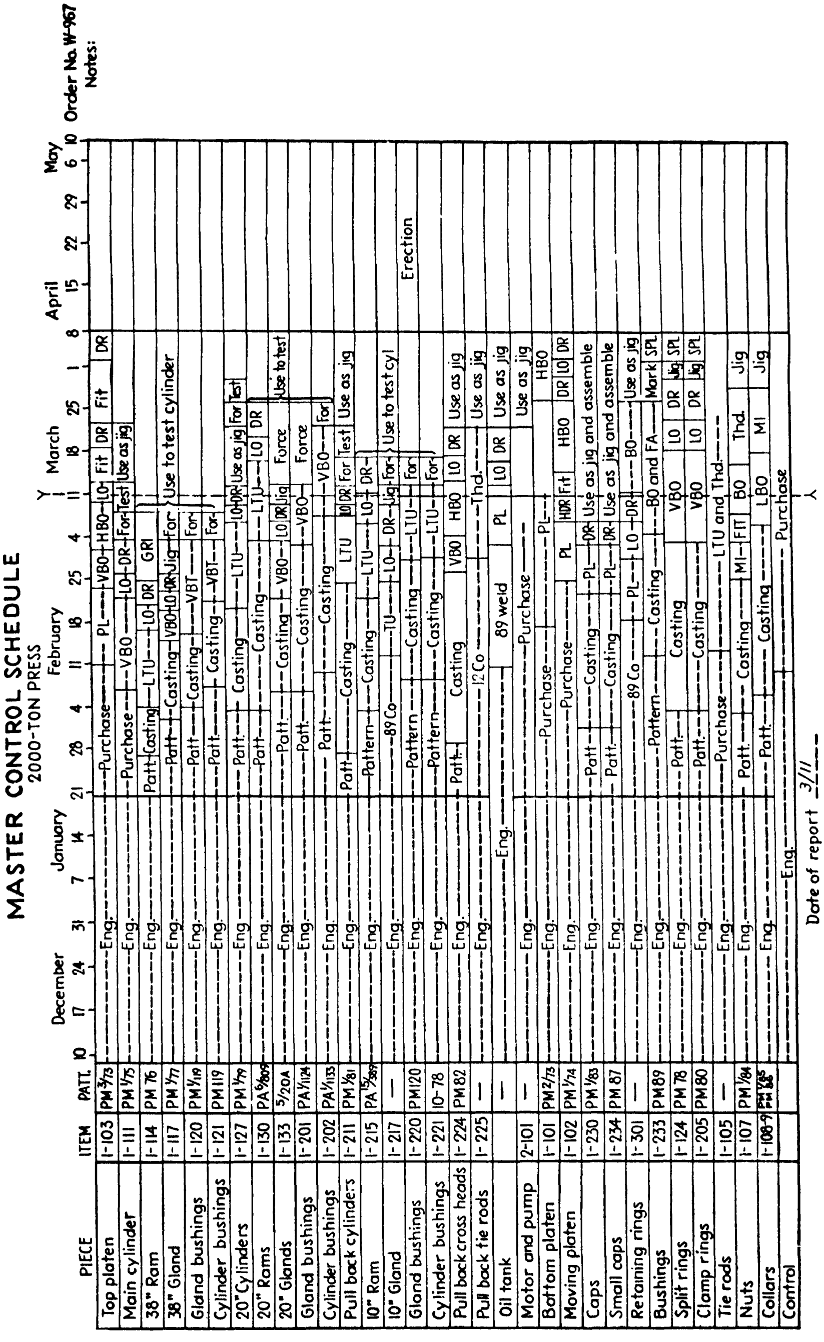

MASTER CONTROL SCHEDULE
2000-TON PRESS
Order No. W-967
Notes:
December 10 17 24 31
January 7 14 21 28
February 4 11 18 25
March 4 11 18 25
April 1 8 15 22 29
May 6 10
PIECE ITEM PATT.
Top platen 1-103 PM 3/73
Main cylinder 1-111 PM 1/75
38" Ram 1-114 PM 76
38" Gland 1-117 PM 1/77
Gland bushings 1-120 PM 1/119
Cylinder bushings 1-121 PM 119
20" Cylinders 1-127 PM 1/79
20" Rams 1-130
20" Glands 1-133 5/20A
Gland bushings 1-201 PA 1/1124
Cylinder bushings 1-202 PA 1/1133
Pull back cylinders 1-211 PM 1/81
10" Ram 1-215
10" Gland 1-217 —
Gland bushings 1-220 PM 120
Cylinder bushings 1-221 10-78
Pull back cross heads 1-224 PM 82
Pull back tie rods 1-225 —
Oil tank —
Motor and pump 2-101 —
Bottom platen 1-101 PM 2/73
Moving platen 1-102 PM 1/74
Caps 1-230 PM 1/83
Small caps 1-234 PM 87
Retaining rings 1-301 —
Bushings 1-233 PM 89
Split rings 1-124 PM 78
Clamp rings 1-205 PM 80
Tie rods 1-105 —
Nuts 1-107 PM 1/84
Collars
Control
Erection
Date of report 3/11

FIG. 22.

The same procedure is followed for all other items on this chart by showing the detail dates for completion of all operations on all parts listed on the chart. It will be noted that erection of this machine was to have been started on Apr. 8 and finished for shipment on May 10.

Interpreting this chart for use in follow-up of scheduled production, it may be noted that the date of this report is Mar. 11, and looking at the chart we see that a dotted *report line* has been drawn across the chart at Mar. 11. This shows clearly that the horizontal progress line for the first item (top platen) has been extended out to the report line, showing that this part is exactly on schedule. The third item (38-inch ram) is considerably behind schedule, as shown by the *progress line*, which is only up to about Feb. 20. Stating it another way, the ram should have been finished about Mar. 7 but on Mar. 11 has two operations yet to be performed.

If an operation falls behind schedule, it may not only delay completion of the assembled product, but may cause other machinery and men to be idle waiting for the completion of that one operation. In such cases an attempt must be made to speed the operation that is falling behind schedule or to plan for the conversion of the time of other men and equipment to other work, thus allowing the schedule on this particular manufacturing order to regain balance.

It will also be noted in Fig. 22 that some operations are ahead of schedule. This is especially significant since it denotes the possibility that certain equipment and personnel may be available for other work sooner than formerly anticipated.

Unlimited combinations of various data may be assembled and charts designed to present graphically the parts in each case. Undoubtedly there are numerous instances in which graph charting is very advantageous, and there are similar instances where the cost of their preparation and maintenance is in excess of their value. Since the maintenance of routing, scheduling, dispatching, and follow-up charts is recognized as a functional responsibility of the production-control department, this same department should also assume responsibility for their proper evaulation from an over-all company standpoint. Frequently charts are designed for plant operation locations and the responsibility for their maintenance placed upon production supervisors or factory clerks. In some instances production operators may be assigned duties in connection with their maintenance at job locations—it is important to remember that having someone else keep the data and do the work required for chart maintenance does not necessarily mean that the charting is obtained without cost. When

supervisors, factory clerks, or production operators spend time on chart data or posting, they are using time borrowed from their specific duties. An elaborate chart control in an instrument plant employing 500 people during the war period is known to have used a force of four men and eight women to maintain the charts according to the standards required. Possibly the cost of the setup was money well spent, but it is hard to appreciate a sufficient increase in production or equivalent improved quality and service resulting from the efforts of 12 people expended in maintaining the charts in this instance.

In conclusion, it must be borne in mind that charts have a definite place in manufacturing and can be used very effectively as a tool to show conditions, but that judgment must accompany decisions as to how extensively they can be adopted economically.

The same consideration applied to internal plant-prepared charts should be given to commercial charts and plans advertised so extensively as production-control systems. Most of them have application as tools to assist in the control of production, but few of them have universal application as advertised.

**Scheduling Job-order Production.** In job-order production, products are made to customers' orders only, and in certain industries repeat orders for some particularly special or heavy types of machinery are unusual. Hence there can be no complete standardization of routing; there is no steady flow of material in process on conveyors; each component part may follow a new path from operation to operation; and often even the time that will be taken for each operation can only be approximated, because the article being produced may be of entirely new design.

*Master Schedule.* Bearing in mind that scheduling is a procedure for determining the time required to complete a job order, let us examine some of the problems that must be solved before a master schedule can be evolved for job-order production.

An example will be drawn from the field of heavy-machinery building, since this industry presents one of the most interesting expositions of some of the problems involved in job-order production. It must be recognized, of course, that each industry may vary in the exact nature of its scheduling problems. General scheduling procedures, however, would be basically the same in all job-order production. Let it be assumed that a steel mill, in the course of a modernization program, has decided to install a rolling mill capable of rolling wider and heavier sheets. In the processes of plate rolling, a large machine tool called a *roll grinder* is used to grind the rolls of the rolling mill as a maintenance

operation in order to maintain the proper surface finish and the proper contour of "crown" on the rolls. A stock of the rolls is kept on hand, and this stock or supply is "rotated" between the rolling mill and the roll grinder—*i.e.*, rolls being used in the rolling mill are removed and reground in the roll grinder, and other rolls that have been reground are installed in the rolling mill for the next run.

For further purposes of example we shall assume that the roll grinder to be purchased and installed by the steel mill is to be of a larger and heavier design than has heretofore been built by our job-order machine builders. When the sales department first makes contact with this prospect and obtains specifications and general requirements on which to base a preliminary engineering design and an estimate, the basis for master scheduling is established. While the preliminary design is in progress, methods engineers are being consulted by the designers to ensure against the possibility of any parts of the roll grinder being designed to such dimensions as would prevent their being machined on existing machine-tool equipment in the machinery builder's plant.

To determine an estimated-cost basis on which to predicate the selling price of the roll grinder, it will be necessary for a time estimate to be made, covering all machining operations and the final erection and testing of the machine. This is done in the case of an entirely new design by estimating only. In the case of a new design that is based on a similar but smaller (or larger) machine, reference can be made to cost and production records on these previous orders. In the case of a machine that is an exact duplicate of a previous order, reference to the past order records will give the time values necessary for the master scheduling.

In the example under consideration, let us assume that before the quotation is made, the time values have been settled and it appears that shipment can be made in seven months from date of order. This information is included in the quotation, and the customer's reaction to the quotation is that, although the price is right, the seven months' shipment quoted is too long and in order to coincide with their mill-construction program they must have the roll grinder in six months' time instead of seven. The order is taken on that basis, and then the real work of scheduling begins. Since the manufacturing time has been cut from seven to six months, some reductions must be made in the manufacturing times previously allotted to each of the five principal divisions involved. This may involve overtime schedules in certain departments and diversion of men and equipment from other

orders that are not so urgent or on which advance progress has been made.

In scheduling job-order production there is no substitute for experience, *i.e.*, there is no substitute for experience in scheduling production orders even remotely similar to the one in question. For instance, the time allotted for erecting and testing the roll grinder must allow sufficient time for adjustments to be made to the machine that will permit it to grind rolls to the exacting standards of dimensions and finish that are absolutely imperative. Unfamiliarity with these standards may lead a novice to believe that the manufacturing department's responsibility is finished when the machine is erected.

There are five principal divisions of operations in the heavy-machinery building industry that we have chosen as an example of job-order production, namely, *engineering*, *patternwork*, *foundry-casting production*, *machinery*, and *erecting*. This division of operations will vary in different industries in accordance with the nature of the product manufactured.

In most cases, master schedules are established by working *backward* from the shipping date. Thus we shall take Aug. 29, which is six months from the date the order was placed, as our base. From records of time used on similar orders plus the "experience judgment factor," we find that four weeks will be necessary for the erection and testing of the order. That time allowance then brings us back to Aug. 1 as the latest date by which all parts must be machined and all outside purchased parts that are assembled with the machine, such as electric motors and controllers, must have been received at the plant.

The amount of machine-hours shown by the cost estimate, modified again by records of past performance on orders even remotely similar and by the very important "experienced judgment factor," show that eight weeks will be necessary for machining operations. This brings us back, then, to June 6 as the latest date by which all the required castings must be delivered by the foundry to the machine shop and, likewise, the date by which all forgings and other raw material or semi-finished material must be available for machine-shop operations. By use of the same reference to records and the same experienced judgment, a period of six weeks has been shown to be necessary for the molding, casting, cooling, and cleaning of the castings, some of which weigh as much as 20 tons. Therefore, we work back six weeks from June 6 and arrive at Apr. 25 as the date by which all patterns must be finished and in the foundry ready for use.

This brings us to a consideration of the time required to make the new patterns that may be necessary, or to change and modify existing patterns that may be used with these alterations. Since this phase of master scheduling is so closely connected with engineering design, close cooperation with the engineering department is necessary. Here we become involved with the imponderables of manufacturing, for it is obvious that patterns cannot be made or changed until the proper drawings are available. The prompt availability of drawings depends on prompt completion of engineering design, but no one has yet devised a means that will enable a machine designer to conceive a design in his mind and transfer it to drawing paper from which it will emerge as a blueprint for shop use in any given scheduled period of time. A portion of the engineering work is creative design, and an ingenious piece of mechanism simply is not conceived in any predetermined time.

However, as the majority of the engineering work involved is not creative design in the full sense of the term but only adaptation and modification of previous work, it is possible to set up a master-schedule date for the engineering department as their completion date, barring the possible "mental stalemate" implied in the previous paragraph. This date is set as Mar. 28, but this, of course, is the *final* completion date for all design drawings. If proper planning, coordination, and control are exercised from the very start of the project, a list of "major" or strategic parts will be made up, and every effort must be made to complete the drawings for these parts in the order listed.

For example, the front and the back beds of the roll grinder are the first parts that will be required in the erection of the machine. Their size and weight make them a problem for the foundry to produce, since the molding time taken is considerable. After being cast, they must remain in the sand a long time so that they will cool without warping and cracking. After they are out of the sand, they require careful cleaning and sandblasting before they can be moved to the machine shop for the rough-machining operation, previous to being taken back to the foundry for heat-treatment to prevent warpage during or after machining. The machining operations are long and involved, yet it must be remembered that these beds must be available to the erecting shop at the earliest possible date.

Hence on our list of major parts will be found the front and back beds. Drawings are issued for these at the earliest possible moment, and the pattern shop begins its work. Thus it is possible for the patterns for these beds to be in the foundry ready for molding long before the pattern-shop completion date of Apr. 25. The same procedure

is followed on other component parts and is simply the utilization of the old rule of "first things first."

The making of master schedules for job-order production requires not only a knowledge of the production-control principles involved but a thorough knowledge of the product and some knowledge of the ultimate use of the product in the customer's plant. A minute and detailed knowledge of the various production processes employed in the manufacture of the product being scheduled is imperative, as is a complete familiarity with the capacities of equipment, such as machine tools, within the plant. Knowledge of the production-control procedure alone is not enough; one must know all phases of his product, plant, and personnel.

# CHAPTER IX
# DISPATCHING

**The Function of Dispatching.** In the preceding chapters we have outlined the procedures and techniques of forecasting, routing, and scheduling, all of which might be termed the preliminary planning steps leading to the dispatch of the raw materials, parts, or subassemblies to the actual manufacturing operations.

Dispatch, then, may be termed the action element of production control, the means by which authority is released to perform the routed and scheduled operations. The release of this authority must be in accordance with the predetermined schedule, but must be withheld until materials, jigs, fixtures, tools, working drawings, detailed operating instructions, operation tickets, time standards, and other essential items are in readiness.

Dispatch provides official authorization and information for

1. The movement of materials to routed workplaces.
2. The movement of tools and fixtures necessary for each operation.
3. The beginning of work on each operation.
4. Recording the starting and completion times at each operation.
5. The movement of work in accordance with the routing schedule to the next operation.
6. Control of the progress of all operations and the making of necessary adjustments in the release of operations to conform to the demands of unpredictable emergencies.

This itemization of the principal factors involved in dispatching rightfully implies that the object of this function is to obtain an evenness in the flow of work in process and at the same time to conform to the requirements of the production schedule. This requires that the work of all departments be coordinated through some central control authority. The extent of centralized control may be affected by many factors present in the general organization of the company and in the type of products manufactured. There is a similarity between the dispatching of production orders to the various plant operations and routing stations and the dispatching of airplanes at large terminals. Materials, parts, and subassemblies are supposed to follow predetermined routings and be at designated plant-process locations at specific

times. Cross-country planes have a schedule of landings to make at definite locations as they traverse the air lanes from the beginning to the completion of their flights. While the planes have greater latitude for detours than the process parts in manufacturing, unforeseen things happen that affect the results. It is possible that whatever happens en route by plane travel may be overcome and a satisfactory completion at the home field accomplished. In production dispatching likewise, interruptions and delays that occur during the process may be corrected and the final assembly completed as scheduled. Planes, at airports along their route, may be held in the air for hours before landing signals are given because conditions are not right—other planes may have gained priority due to various causes that make it impossible to maintain the original schedule. Process production, too, may not give the predetermined priority to certain jobs, because of machine breakdowns, material shortages, other job priority, and numerous other interruptions that occur to cause the routings and schedules to be changed. The dispatcher must rely upon the expediting and follow-up service described in Chap. X to obtain information for changing his plans. In the same way, the air-terminal dispatch engineer must be kept informed by his weather advisers. He must also be kept informed by communications engineers in the planes of their identity so that adequate facilities may be made available before signaling the planes to land. Thus it may be concluded that most situations can be satisfactorily handled, provided all facilities at the disposal of those who are to direct and make decisions are properly utilized.

For the movement of the production process the factor of greatest influence is the restriction of time between authorization and operation. In continuous manufacturing under normal conditions, orders may be dispatched to departments well in advance of operations, provided the sequence conforms to the predetermined schedule. In this type of organization, each department may prepare its own job orders and authorizations for each operation and send duplicates of these authorizations to the central office. If, in the opinion of the central office, certain operations are being delayed beyond the essential requirements of production, the office may seek to obtain an earlier starting date through communication with the various departments and an attempt to make needed adjustments. Similarly, the central office may ask one department to delay operations on a given order so that it will not get too far ahead of schedule or ahead of the work of other departments.

It is obvious that under this arrangement considerable time between authorization and operation is required for these communications to pass back and forth between the office and the various departments and for agreement to be reached on final authorizations for the beginning of operations.

Under normal conditions the necessity for these changes in authorization might be of limited frequency and of little disturbance to production. However, at times when the company is operating under extreme pressure to meet delivery dates, these emergency changes are likely to be more frequent and the loss of time of greater importance. The demands of customers may make it necessary to change the schedule and give certain orders priority over others. This may mean that operations must start immediately and other orders originally scheduled be laid aside until the rush order is completed. Circumstances such as these reveal the value of a centralized procedure and well-coordinated dispatching system. Through centralized procedure the central dispatching office has up-to-date information regarding availability of materials, equipment, and personnel, in addition to the routing and scheduling requirements. Through this information it is able to act immediately to analyze the production limitations and authorize necessary adjustments. Without centralized procedure, the central authorities may be unaware of production limitations and difficulties involved in making the required emergency changes. In other words, centralized control may lead to greater immediate flexibility in times of stress and may also bring greater efficiency and economy in the making of necessary adjustments in the production schedule.

**Centralized Control through the Use of Planning Boards.** The dispatch clerk under a centralized procedure must have some means of obtaining an accurate and immediate check on the progress of work in the shop and the orders that are awaiting authorization. The best single aid is a central planning board. The construction and organization of the board should be varied in terms of the needs of a particular company. One very simple type has the appearance of a bulletin board on which there are three rows of hooks. Each set of hooks represents a work station or operation in the plant. The purpose of the hooks is to hold the dispatching forms representing jobs that are now in operation or jobs that are to be performed at the workplaces represented on the board. The first vertical row of hooks represents the work now in progress. The second row represents the work that is at the workplaces awaiting operation. The third row represents the work that has been tentatively scheduled to the workplace but has

not been officially dispatched. Compartments or pigeonholes are usually built into the board for each workplace and for the purpose of filing various instructions regarding the work to be performed.

Another type of board, illustrated in Fig. 23, involves the use of a circular rack designed to hold a number of boards according to the demands of the company. The equipment illustrated consists of 60 boards. Each side of the board has 77 springs, 7 horizontal and 11 vertical. Each spring represents a machine, workplace, or a part in

FIG. 23.

process, and is designed to hold a maximum of 50 tickets containing directions, authorizations, and progress reports.[1]

Among the more common forms dispatched are

1. *Work Orders and Operation Tickets.* These authorize a department or an employee to start work on a certain lot of material and also serve as a means of recording the production performed on that material.

2. *Time Cards and Other Wage-payment Cards.* These are used to report the time utilized by each operator in the performance of work on a lot of material, and to supply other vital information used in the preparation of the pay roll.

[1] CONOVER, L. G., "A Glance Tells the Status," *Factory Management and Maintenance,* August, 1941, p. 104.

3. *Inspection Tickets.* These are used to report the quantity of work passed and the quantity rejected at each inspection operation.
4. *Move Tickets.* These authorize the movement of material between operations.
5. *Tool, Gage, and Equipment Tickets.* These must be furnished to the toolcrib or gage room before such equipment can be supplied.

The type of board shown in Fig. 23, is particularly adaptable to the needs of a large company manufacturing a diversified line of products.

Dispatching of successive jobs to the same workplace is merely a series of repetitive receipts of finished job and "sendings" of next jobs. It is customary to record the item on each job ticket as it is dispatched to the workplace and also as it is returned. This procedure makes possible a calculation of elapsed time on each job by subtracting the two recorded times. By arranging the job tickets in the order of their time recordings, the total time expended at a particular workplace by an individual or group of operators may be determined.

As a dispatching expedient, the schedule board is the most satisfactory. The principal criticisms are (1) the amount of time required to keep the board posted through the changing of job tickets, and (2) the possibilities of inaccurate reporting of beginning and ending times. The latter is caused through the operator's laxity in sending finished jobs back, or through his misrepresentation of starting times by having the next job dispatched to him before he has completed the one on which he is working. Such misrepresentation is relatively easy unless there is continuous supervision by which the job tickets are compared with work being performed. Since the schedule board and dispatcher's desk may be centrally located, but at the same time in a position remote from the production workplace, it provides very little opportunity for detecting infractions by operators in performing the work covered by the job tickets dispatched to them.

**Department Planning Boards.** The second criticism noted in the preceding paragraph may be at least partially eliminated through the use of duplicate planning boards located in each department. Each of the department boards shows the work of only that department, in the same order as it is arranged on the central planning board. When department boards are used, each job is dispatched to the department instead of direct to each workplace. The worker or group leader secures his orders from the department dispatch desk and returns the job ticket upon completion for recording the time.

The department board is for the use of the foreman in supervising the work of his department. It affords a means for keeping an ac-

curate check on the work and eliminating errors and misrepresentations in the time recordings on the various operations. The value of department boards in a centralized system is seriously to be questioned. Each company should consider the costs involved in the duplication of posting to the boards and the loss of time by operators, particularly in a large department where the workplace is a long distance from the dispatch desk. These costs should be compared with the possible aids to accuracy of time recordings and facility in planning and supervision.

**Movement of Material to Successive Operations.** Dispatching of work from one workplace to another may be aided by use of the planning board through placing a copy of an information job ticket with each of the authorizations for operations that are to be dispatched. This instruction job ticket is called a *move ticket*. It can be located in such a way that the movement of materials to the next workplace will be authorized at a time that will coincide with the prearranged schedule for the workplace to which the material or parts are to be moved. The proper functioning of this arrangement will coordinate the dispatching of materials and authorization of operations at the workplace.

**Dispatch Communications Facilities.** Different methods of transmitting the instructions and authorizations are used in various plants. The methods employed consist of the following:

1. *Messenger Service*. This type of service may include the use of regular plant mail service as well as that performed by representatives of the dispatching division.

2. *Pneumatic Tubes*. These have been employed in a number of plants with considerable success. Steel vacuum tubes usually radiate to and from a central dispatching station and the various department centers. Carriers made of a transparent plastic are provided so that the destination of the contents may be easily read.

3. *The Telautograph*. This is a commercial installation used to transmit sketched and written orders instantaneously to the department or individual concerned. The sender holds a pencil-like stylus with which he writes on a plate. The sending stylus is mechanically connected to a pair of rheostats set at right angles to each other which serve to vary the voltage at the receiver and thus to translate the impulse into pen motions on recording paper at that end.

4. *The Teletypewriter*. This is the standard teletype machine, similar to that used by the telegraph companies and by newspapers. If machines are spotted at key work centers through the shop or in

each of several widely separated departments, the system can then be used to transmit dispatching information and to report production information in return.

5. *The Telephone.* The telephone has in many plants been overlooked as a dispatching and reporting device, primarily because it has been considered an inaccurate medium for transmitting letters and figures. However, this is not altogether true. A telephone properly employed by trained operators can be a very swift and accurate facility. If proof is required, the Southern New England Telephone Company has long dispatched its installation and repairmen by telephone, transmitting the job number and all other pertinent information via the phone. Its principal advantages are its speed and the fact that the communication is on a personal basis; its disadvantage lies in the fact that no permanent record is available for messages thus dispatched.

6. *Interstation Loud-speaker Devices.* These are essentially multiple-station amplifying units over which conversations can be carried. Each station consists of a small cabinet containing a microphone and speaker. At each station, communication is afforded by simply throwing the switch for one or more of the stations with which contact is desired and talking in a normal voice.

Selection of communications facilities must always be based on the requirements of the communications involved in any one plant. Factors of (1) speed of transmission, (2) accuracy, (3) recording of the communication, (4) personal contact, and (5) cost, must all be weighed one against the other. Usually a combination of facilities will be required. The telephone or interstation speaker system may be used for frequent follow-up and for emergency changes between the dispatcher, the various work stations, the toolroom, and the stock room. Where a permanent recording is desired, a telephone communication may be followed by some form of written communication delivered by the plant mail system or by special messenger. Some jobs may require a considerable volume of instantaneous transmission of written messages, making the telautograph, teletypewriter, or a pneumatic-tube system worthy of consideration. And of course in all these instances it is important to consider whether the advantages to be gained justify the cost in terms of both installation and operation. Analysis will frequently show that added communications equipment installations will more than pay for themselves in savings of the time of messengers, typists, and mail clerks. To such savings, of course, must be added the possible saving in direct labor and machine time resulting from the avoidance of production delays, the value accruing to the

company from improved customer service, and the consolidation of shipments made possible by the maintenance of schedule.

**Dispatching Customers' Orders.** Dispatching customers' orders to the manufacturing plant is a function of the sales department or some intermediate department such as a sales-production-coordination (S.P.C.) department. It differs from the dispatching of material or parts orders within a plant to the extent that the destination is usually the order department instead of the various workplaces, machines, or work stations throughout the plant.

Dispatching customers' orders is less detailed and has fewer complications than dispatching the parts of those orders through the plant. Customers' orders may be dispatched daily, weekly, or monthly. The principal concern of the dispatcher is that the quantities conform to the master-schedule rates projected for the period. Completion dates may cover an extensive period of as much as six months. In cases in which the number of immediate-delivery orders may not be sufficient to keep the plant in continuous operation, future delivery orders and stock orders may be dispatched as supplements. If delivery dates make it possible to group the schedule of orders for products of similar type, thereby reducing the number of changes in the arrangement of equipment, material, and personnel, it is obviously desirable to do so.

**Dispatching by Load Charts.** In scheduling work necessary to produce the quantities of products planned in the manufacturing schedules it is advisable to use a load chart to control the volume dispatched, thus providing ample work, yet preventing overloading. The simplest type of chart is sufficient in most cases, since all that is required is a means of showing capacity figures, against which are posted the jobs as they are dispatched to the operations. In view of the fact that the chart is to be loaded progressively throughout a work period, it is more effective to arrange the capacity figures on a progressive basis in order to show periodic progress. For example, on an operation to which 800 units are to be dispatched during an eight-hour shift, an average of 100 per hour should be completed. Therefore chart records arranged to show each hour from 8 A.M. to 5 P.M. would provide a chart from which the progress could be checked at any time.

**Dispatch in Job-order Production.** Under a well-ordered system of production control in a plant devoted to mass production or continuous-process production of similar goods in large quantities, the element of dispatch, once the proper procedures are established, becomes a matter of routine functioning of established steps for movement. The dispatch of material and tools for the manufacture of

10,000 units for one stock order, all alike, although calling for huge quantities of material and an equivalent quantity of equipment and personnel, is a relatively simple dispatch problem compared to the dispatch of material and tools for the job-order manufacture of only 1,000 units for 500 individual orders, the majority of which differ from the others to some degree, often with no similarity of any kind in size, operations, or even in material.

Consider a plant manufacturing radio receivers of sizes varying from portable models up through console models to large radio-phonograph combinations. Stock orders would be manufactured in quantities varying from, let us say, 10,000 small models to 100 large combinations. A few parts are common to all models. Let us assume that there will not be more than 20 variations or models. However, they are made up in lots varying from 100 to 10,000 and are manufactured on the same machines and presses and by the same processes.

Now let us consider a plant devoted to the building of process machinery and special equipment made to customers' specifications. This requires a job-order production system, since all production is in terms of specific orders. At the same time that our hypothetical radio manufacturer is producing his assumed 20 models, our machinery manufacturer's records disclose the fact that in the operation of his business he has entered over 1,000 separate manufacturing orders for 700 types, sizes, styles, and classifications of machinery and equipment. The closest he has come to repetitive manufacturing is on an order for 36 rolling mills of a type never before designed or built. The finished weights of complete units or machines vary from 1,500 pounds to 300 tons, with weight of component parts varying from 3 pounds to 65 tons.

The production records of the manufacturer of machinery indicate that the number of units on a shop order varies from 1 to 36, with the number 1 appearing 96 per cent of the time. Some of the plant equipment is utilized on only 5 per cent of the shop orders under production at the time our survey is made.

An examination of the orders in process reveals that the machinery manufacturer at this time is producing rolling mills for rolling brass, mixing mills for preparing compounded stocks, calendars for processing fabrics for tire production, reduction gearing for propelling oil tankers, sugar mills for grinding sugar cane, huge hydraulic extrusion presses for extruding duralumin tubing for aircraft, paper-calendering machinery, generators for generating gear teeth, roll grinders for grinding mill rolls in steel mills, aluminum mills, and paper mills, and reduction gearing for naval vessels of all types and classes. These

are complete machines only; superimposed on this load are many maintenance orders for repairs, spare parts, etc., all different.

There is no easy solution to the highly complicated problem of dispatch in the job-order industries. The preceding description of dispatch in general applies as well to job-order production. More personnel is required to dispatch an equivalent dollar-volume of business and, generally speaking, must be better trained and more broadly experienced in a particular business in order to be familiar with the many variations of routing and processing that are encountered.

### CASE 10. SCHEDULING AND DISPATCHING

*Royal Firearms, Inc.*[1] Royal Firearms, Inc., is about to move into its new branch plant, and the production officials are wondering how best to set up the necessary control to plan and meet schedules. The branch is to make several standard lines of firearms and is organized under a departmental setup whereby several operations are performed in a single department before the work moves to the next department. The material must move through eight departments before completion, and it is expected that as many as 300 different production or manufacturing orders may be in process at any one time.

In the main plant, under a similar production setup, a simple control system is in operation. As each lot of material is authorized to be manufactured, a production order is made out in duplicate, one copy being filed in a cabinet-type file in the office and the other being sent to the first department. The production order contains a schedule of the planned starting dates for that lot of material in each of the manufacturing departments concerned. As soon as the raw material is delivered to the first department, a copy of the material delivery ticket is sent to the production office, and a clerk pulls the office copy of the production order from the file and posts on the order the amount of material, after which the order is again filed back in place.

Once the first department starts to work on the material, it sends along the departmental copy of the production order to the next department, and this procedure is repeated at each of the successive eight departments concerned. As soon as the first department finishes all or a portion of the order (*i.e.*, has completed all the operations performed in that department) the clerk of that department makes out a move ticket in triplicate showing the material, the quantity, the order number, and the date completed. The original is sent to the next de-

[1] Name fictitious.

partment with the work, another is retained in the originating department, and the third goes to the office where the above-mentioned production clerk posts the information on the production order.

Control is limited to departments, no attempt being made by the production men to break down the process into individual operations. Control over operations is decentralized in the hands of foremen, for the opinion prevails that with a standard line of goods all following the same general sequence of operations and departments, an operational breakdown is not necessary. It is felt, however, that the system used in the main plant has the weakness of involving a great deal of filing, posting, and refiling of production orders and does not permit easy detection of production delays. The only way of detecting an order that has remained too long in any one department is to have the production clerk periodically run through the office file, pull out any "late" or delayed orders and go out to the departments concerned to investigate the trouble. However, this is rather a hit-or-miss follow-up system that strikes only those orders that are already long overdue and does not appear to make for a very positive type of control.

### Preparatory Question

Recommend the type of scheduling and dispatching control you feel the Royal Firearms company should install in its branch plant.

### CASE 11. SCHEDULING AND DISPATCHING

*Weldon Weaving Mills.*[1] The Weldon Weaving Mills operate some 400 looms in the weaving of rayon cloth. Recently a change in the organization resulted in a new individual taking over the scheduling of the orders on the looms, and he, on assuming his duties, found a rather unwieldy system in use.

Warp tickets (which were essentially manufacturing orders) were made out in duplicate. The originals were filed away in a drawer under the warp-ticket serial number, and the duplicates were given to a dispatcher whose duty it was to make the rounds of the looms twice a day. At each loom was a holder designed to take the duplicate copies of the warp ticket. In making his rounds, the dispatcher would remove from the holders any tickets on jobs already finished and would notice looms that were out of work or that appeared to be in danger of running out before his next visit. At such looms he would leave the duplicate ticket for a new job. If it became necessary, as it did rather frequently, to ascertain the progress of a certain job, the dispatcher

[1] Name fictitious.

had to be sent out on a special trip to the looms to find out where the job was being run and what progress had been made on it.

The new man in charge of scheduling felt that some better means of scheduling and dispatching the work could be devised to enable him to control it from a central point and to keep him informed at all times as to which jobs were running or scheduled to run. Also, he felt it should be possible to eliminate much of the idle loom time that resulted from the looms frequently running out of work between visits of the dispatcher.

## Preparatory Question

Suggest any specific changes in procedure that you would recommend that the Weldon Mills make to improve its scheduling and dispatching.

# CHAPTER X

# FOLLOW-UP—EXPEDITING

In a certain sense follow-up and expediting are duplications of other functions, considering that if everyone involved in manufacturing could be depended upon to do his job as he is supposed to do it, follow-up would not be necessary.

The scope of the follow-up function may well be considered as extending from the sales-department forecast of anticipated business to the payment of invoices on delivered merchandise, and in some instances to the analysis of customers' claims on returned merchandise. The follow-up personnel assigned to see that sales forecasts are met may be the sales manager, but someone reporting to the sales manager may be delegated the responsibility for analyzing sales by individual salesmen or territories and periodically reporting to the sales manager those which are not meeting their quotas. The individual salesmen probably know better than anyone else how they are doing, but the fact that periodic follow-up procedures show comparisons encourages them to maintain a good standing and supplies the little added push that makes follow-up worth while.

**The Scope of Expediting Service.** It is not the intention of the authors to create the impression that there are not good and sufficient reasons for failures to meet commitments. From the standpoint of an individual or a specific group, the most logical excuse is a shortage of material, but our treatise does not end with the shortage—the important consideration is what expediting or follow-up would have prevented the shortage. A shortage of subassemblies may be traceable back through several preparatory processes: the subassembly shortage may have been caused by a shortage of parts, caused in turn by a shortage of processed material from which they were procured; the processed material shortage may have resulted from failure of another company to meet a delivery commitment on an ingredient essential to the preparation of the raw material required. So the question, Where is it important to maintain follow-up procedures? may be answered in this way: they should cover every point in the process that has given chronic delivery troubles.

In regard to the degree of follow-up required by different types of industry, it is generally recognized that those manufacturing direct to customer orders have greater need than those producing for warehouse stock.

**Organization for Expediting and Follow-up.** Some plant managers consider that the expediting of work through departments is the foreman's responsibility, and that if he is doing his job properly, organized expediting is superfluous. There is some merit to this contention, but experience has shown the necessity despite the foreman's efficiency. Too often delays in processing within any department are not the failure of that department but are traceable to the shortage of promised materials, parts, or subassemblies by the purchasing department. Furthermore, foremen in manufacturing concerns today are too valuable to production and quality to spend their time "chasing stock." This can be handled best by an organization especially set up for the job, which will be responsible for expediting the work and will require a minimum amount of the foreman's time.

The follow-up procedures required for serialized continuous-flow production differ greatly from the type used for job-order production. In serialized production the departmental foremen and supervisors may perform what is essentially a follow-up function in their daily routine responsibilities of keeping production flowing through their departments. It resembles an endless chain situation in which a broken link means an interruption and everyone's attention is directed to the location of the trouble. Generally a major repair is necessary to get the chain back into operation; the break cannot just be moved to one side and service continue normally.

The situation may be quite different in job-order production, especially where controlled banks at stations are the practice. Usually the next job is "on deck." A shortage of material on the current job may merely mean that that job is temporarily sidetracked in favor of the next for which there is material. However, herein lies a danger if such decisions are left to the operating unit. It is quite easy for an operator or operation group to rationalize that other factors, such as saving on setup time and added operator earnings, might also be sufficient for the rearrangement of predetermined schedule. This danger only emphasizes the need for follow-up by neutrally interested expediters.

Expediters may function from a central department, or they may be part of a departmental organization. In either case some centralized coordination is necessary. In the departmental organization

the scope of the expediter's responsibility would extend from the arrival of the job into the department to its completion in that department, and then the next department expediter would perform similarly. In the centralized, plant-wide type of follow-up organization the expediter has a responsibility of wider scope, cutting across departments and enabling him to follow a product to completion. This type of organization tends to give better results, mainly because of the product interest it creates, by comparison with the operation interest of the department expediter.

A third type of organized follow-up procedure is a combination of the departmental and centralized types, whereby departmental expediters concentrate on materials and parts service within their respective departments, while a centralized force is responsible for the follow-up of subassemblies between departments until final assembly is completed.

Some companies have found it quite advantageous to have certain accounts assigned to the members of the production-control department who are responsible for the follow-up procedures in the plant. All orders scheduled for the accounts thus assigned become the responsibility of the expediter from the start of production until completion. Any interim correspondence in connection with the orders is likewise handled by the expediter, as he is best qualified to answer service questions that arise.

**Expediting into the Plant.** Follow-up and expediting procedures are generally recognized as internal plant necessities, but there are numerous instances where *in transit* follow-up plays an equally important part in supplying needed materials, parts, and products on schedule. This type of follow-up is usually conducted by purchasing and traffic department personnel working through agents of the public transportation carriers. The follow-up may consist of checking shipments that have been made or arranging for special attention to be given to contemplated shipments in order that they may be kept moving. The problems are much the same, whether they are to keep materials moving between departments and operations within a plant, or between stations and through terminals while in transit. The possibility that materials may get sidetracked is a hazard in both instances.

The follow-up procedures as applied to the financial end of the business are recognized responsibilities of the accounts-receivable department and differ greatly from the production expediting. With proper credit-approval procedures in effect, the follow-up required on accounts with reputable concerns may be relatively simple. Usually

such customers attempt to obtain full discount advantages by payment without follow-up. Those requiring follow-up should not constitute the repetitive situations experienced within the plant, since the credit policy should either improve them or eliminate the more chronic offenders as poor risks.

**Follow-up of Materials.** Best practice dictates that follow-up of materials should start with a follow-up of the requisition on the purchasing department for the materials. Possibly the best method of control in this regard is for the production department, in originating the requisition, to make it out in triplicate and to send all copies to the purchasing department after first posting the amount requisitioned on the material-control records. The first copy can be retained permanently by the purchasing department as its record of the requisition. The second may be retained temporarily by them and may later be sent to the production department as a receiving notice from the purchasing department for that material when it is received, or it may be used to convey price information to the cost department. However, it is the third copy with which we are most concerned here, and this copy should be marked to show the name of the vendor and the delivery date promised and then be returned to the production department. When this information is entered on the material-control records, the requisition can be filed in a tickler file according to date of delivery as promised. The production department can then use this file as a means for clearing with the purchasing department on requisitions that become overdue.

However, the responsibility for the follow-up of purchased materials rests primarily with the purchasing department. Depending on the volume of purchases, one or more men in the purchasing department should devote part or all of their time to the follow-up of overdue purchase orders. There are two common methods used to follow up purchase orders. Where major production materials are involved and where a number of separate orders have been placed with each of several vendors, it is usually very helpful in the follow-up of late orders to make out a follow-up sheet for each vendor and to list vertically all purchase orders placed with that vendor. Sufficient space should be provided horizontally to list the months of the year, and the shipments on each order can then be noted under the month for which they are promised. In discussing shipments with a particular vendor, the purchasing agent merely has to look at the sheet for that vendor and to glance down the monthly columns to ascertain which deliveries are due or overdue. Where supplies, tools, and other similar materials are purchased from a wide variety of vendors,

a duplicate copy of the purchase order may be filed by promised delivery or due date in a visible file or in a cabinet file for follow-up purposes.

Very often it is of extreme importance to the production department in its efforts to maintain schedules that the delivery promises on some critical materials or sizes be rigidly maintained, whereas others for which an adequate inventory bank has been built up may not be so critical. Such a condition may be brought about by the scarcity of certain materials in a peacetime or war-stimulated boom period. It then becomes the duty of the production department to aid the purchasing agent in his follow-up by furnishing him with information as to specific materials and supplies that are most needed and the dates for which they will be required, in order that a special attempt may be made to obtain adequate inventories of these materials.

During a boom produced by a war economy, articles vital to the defense of the nation usually receive a preference or priority rating that may be extended by the manufacturers of such articles to the vendors of needed raw materials so that preference may be given in the supplying of vital materials to such manufacturers. When a system of priority ratings determining the allocation of vital material is in effect, it is the duty of the production department to aid the purchasing agent by supplying him with specific preference ratings that may be used in placing orders for such material. Since requirements and ratings affecting vital material are often subject to change, the purchasing agent must be kept informed of changes as they may occur in order that his follow-up system of vital purchases may operate most effectively.

Routine follow-up of overdue purchases employed by most companies consists of a printed form providing for pertinent information such as that contained below:

1. Name and address of vendor
2. Our order #__________ Your order #__________
3. Article________________
4. Promised delivery________________
5. When will you ship________________
6. When may we expect delivery________________
7. Reply desired________________

Signed by________________

COMPANY NAME

In addition to the purchasing department follow-up, some companies follow the practice of having a similar setup in their order department, whereby a notification reminder sufficiently in advance of the promised delivery is originated and sent to the customer, confirming expectation of ability to deliver as promised. Most companies follow the commonly accepted business practice of notifying customers of expected inability to meet promised dates. Thus it becomes obvious that some means within the supplier's establishment must be provided from which this information can be obtained. It is likewise obvious that the best means of getting the information is from a follow-up and expediting service extending into the operation departments of the supplier. Since so much manufacturing activity is interwoven, the finished products of one manufacturer becoming the raw materials of another, and since follow-up and expediting are accepted as necessary means of meeting delivery commitments, we find an unending cycle of activity. Instead of being limited, this process is recognized as of maximum value when extended and applied to all manufacturing, despite the apparent duplication of effort and in the realization that none of it would be necessary if everybody could be depended upon to meet his commitments.

**Follow-up of Work in Process.** Once the material is received, the receiving inspection department or the purchasing department should notify the production department, and the information should be posted on the material-control records, indicating that the material is available.

Continuous or line production simplifies the problem of the follow-up of material in process, for the problem then becomes one merely of scheduling and dispatching the material in the correct sequence at the first operation. Manufacturing orders and materials may be issued at the time and in the sequence desired to the departments performing the first operation on each part. Once the material enters the process, however, it cannot easily become sidetracked, and it can readily be located at any time. Thus, with continuous or line production, follow-up consists primarily of checking the materials required and watching the maintenance of schedules.

The follow-up of process material connected with diversified manufacture is usually somewhat more complex. The sequence in which materials and parts enter the process in diversified manufacture can likewise be controlled at the first operation by scheduling and dispatching, but after the first operation in the manufacture of such products, control may become mainly a matter of follow-up. The

sequence in which the orders are run under such conditions will usually be decentralized into the hands of the foremen, subject to the advice and judgment of the follow-up men in whose hands usually rests the responsibility for bringing together at the right time and place all the parts necessary for the assembly. The more diversified the parts and the products manufactured, the more difficult becomes the task of follow-up.

The follow-up of diversified manufacture may be organized by products or by departments. Under the former system, a follow-up clerk—or a number of them, if the size of the business warrants—is assigned to follow a particular product through the manufacturing operations to completion. But on the other hand, where the follow-up is organized by departments, one clerk follows material for all products through a particular department, and when the material is moved to another department, a different clerk assumes responsibility for it. The latter method is perhaps in more common use. Where the follow-up is organized by products, it is a common occurrence for several follow-up men, each interested only in the progress of his own material, all to be hounding a foreman for the use of a particular group of machines or operators. But where the follow-up is arranged by departments, the follow-up man for each department is better able to advise the foreman wisely as to the most effective use of his equipment.

Regardless of the organization of the follow-up squad, it should operate on the principle of exception; *i.e.*, it should not be required to follow every article of manufacture through the operations but rather only those articles for which the customer has asked and has been granted a rush delivery or for which he has specified some particular departure from standard procedure such as to require special handling. If, however, rush or special orders become a large percentage of the total production, the exception then becomes the rule, and follow-up must then become either extremely costly or very ineffective. The company that repeatedly asks its follow-up men to rush one product and then the next day asks them to give another product the right of way at the expense of the one rushed the day before never achieves good follow-up control, nor can it expect much cooperation from the foremen.

**Assembly and Erection Follow-up.** Despite the best efforts of the production-control department to expedite parts through the various manufacturing processes, the net result of its work will come to naught if proper control procedures are not followed to the point

of assembly and erection. This final process or operation involves not only the collection of parts processed in the plant, but often the various parts supplied by outside suppliers, such as electric motors and controls, ball and roller bearings, bolts, nuts, washers, and screw fastenings of various types.

This involves a particularly close watch on suppliers' delivery promises, as described heretofore. Instances abound in which great effort has been expended in machinery or in otherwise processing the component parts for a complicated machine, only to have final erection and shipment held up by inability to obtain delivery of some part, accessory, or fitting ordered from an outside supplier, who, at the last moment, failed to deliver—and often for a good manufacturing reason, such as hazard of manufacture, inability to obtain raw material, etc.

The experience of a large number of companies would seem to indicate that there is no solution to this problem except eternal vigilance on the part of the follow-up man detailed to the assembly department or erecting shop. One plan that is in use in many plants, especially in the medium- and heavy-machinery field, is to designate specific follow-up men as the "father" of a particular job or contract. The man so designated is required to carry with him at all times a complete and up-to-date record of the progress of his contract or contracts so that if a question arises he can at any time give information regarding the operations yet to be performed on component parts, shortages still existing on purchased parts, or status of replacements for necessary parts that have been rejected for any reason whatsoever—in short, to be able to produce on short notice a current progress report on the status of the contract or contracts for the expediting of which he is held responsible.

Yet even with this type of control, errors occasionally occur and will continue, since all follow-up is conditioned by the chance of human error.

Many systems have been installed at great cost, involving thousands of pieces of paper in the shape of printed forms; yet the final result of the production-control system in plants in which such systems are installed has been determined by the ability of the production-control manager and his assistants. No system can ever take the place of genuine interest and whole-hearted human effort intelligently applied and directed. And so it is with assembly and erection follow-up—in these departments we shall find a very good yardstick to measure the ability and value of the production-control system.

**Control of Erection and Servicing in Customers' Plants.** With many types of products, especially in the machinery field, it is often necessary to maintain a staff of skilled mechanics who are available for service in customer plants to erect and service machinery that is being installed. This naturally requires a high type of man. Besides his mechanical skill, he must possess a high degree of acceptable personality, diplomacy, and tact, together with the ability to make decisions that will commit or affect his company.

Some companies, with this added problem as a feature of their work, have found it advisable to maintain a schedule board listing each erection mechanic engaged on such outside work and giving his present location, the number of days or weeks he is expected to be at that location, and the location of the next outside job to which he may be assigned or, if not, then the date at which he may be expected back in the shop.

The sales department usually conducts negotiations with the customer regarding the services of the men. Since it is usually the function of the production-control department to route the erection and service mechanics from job to job, provision must be made for close contact between the sales and production-control departments.

**Follow-up Methods and Practices.** The duties of the follow-up men are essentially to provide information. They should inform the foremen as to the sequence of work required and the production office as to the progress of such work, in order that steps may be taken to achieve the best control of schedules and to aid in furnishing the customer with the best delivery information possible. Thus they are essentially go-betweens, whose prime duty is reporting. They should continually ask the question, "Has this been done?" and, "If not, why not?"

Follow-up men should never demand action of the foremen but rather should recommend or suggest steps to be taken. To a great extent the effectiveness of a follow-up man depends on his ability to handle and deal with people. The man who knows how to get along well with people can obtain their cooperation much more readily than can the man who must bluster and threaten to get action. A recent case example might serve to clarify this.

One Friday morning a ship put into New York harbor badly in need of the repair of some of its copper tubing. A telephone call was put in to a Connecticut concern asking if such tubing could be supplied by Tuesday morning, the day the ship was scheduled to sail. The company agreed to try to supply the tubing, but was then faced with the problem of selling one of the shop foremen on the necessity

for disrupting his preplanned schedules to handle this special order. One of the production clerks approached the foreman, told him the story behind the order, and then said, "Sam, it's up to you. Shall we accept the order and help them out?" He had no doubt of Sam's answer and of his cooperation, which he promptly received, to make the delivery as promised. How different might have been the result had the production clerk said, "Sam, you will have to break up your setup to run this rush job. We must have it ready to go by Tuesday morning." Thus it can be appreciated that the technique of handling men is one of the prime requirements of a follow-up clerk.

**Personal Follow-up.** In addition to the follow-up of production orders discussed up to this point, there is a type of personal follow-up that is a part of the daily activities of every production man from the works manager to the foreman and the newest production clerk. It enables the production man to check up on the fulfillment of the promises of others and serves to remind him to carry out his own promises. For example, the schedule clerk may have received a promise from the purchasing agent that a steel shipment needed to make a particular part will arrive at the plant on a certain day. He should then have some method of calling his attention to the expected shipment on the day for which the shipment is promised. Similarly, the clerk may wish to remind himself on a certain day to review the production record of some key machine that has developed machine trouble in order to ascertain what steps may be necessary to make up the production time thus lost.

This type of personal follow-up is usually accomplished by the use of a follow-up file or book. Perhaps the simplest and most inexpensive means is by the use of a book with a page for each day of the month. Notes, cards, and memos can be inserted in the book at the day for which the follow-up is desired. A similar but more elaborate method of accomplishing the same daily follow-up involves the use of one of the standard follow-up metal files now on the market.

### CASE 12. ERECTION AND SERVICING

*Midland Company.* The Midland Company, located in the Midwest, was originally engaged in the manufacture of automobile crankshafts. One of the operations required in the manufacture of crankshafts is the heat-treatment of the bearing surfaces. The Midland Company developed a high-frequency induction heater for the localized heat-treatment of these surfaces. This heater proved to be far superior to any other heating method previously devised, and the

[1] Name fictitious.

major automobile companies requested that the Midland Company manufacture and sell them similar machines for use in their plants.

Once the Midland Company had entered the then rather new field of induction heating, it experimented with its heater and found that the applications of the principle to industrial heat-treatment were almost unlimited. The rapidity with which steel could be heated by this method, thus eliminating the "soaking" period required in furnace heating, made it ideal for locally hardening, drawing, or annealing steel articles of all sizes, shapes, and descriptions. Thus the company devised various quenching devices and holding fixtures to meet special requirements and placed its heater on the market.

One prospective customer, located in the East, inquired about the use of an induction heater for treating small work. The Midland Company agreed to adapt one of their machines to such an application and to install it in the customer's plant on approval. However, the Midland Company was faced with the problem of deciding on what basis to erect and service the machine made for this customer. The problem was made especially difficult by the fact that the prospective customer would be the first in the eastern part of the country to purchase the heater.

Erection of the machine, including the making of initial adjustments and the subsequent servicing, was complicated by the type of machine construction. The rather ingenious means of developing high-frequency current in the machine required complex electrical circuits and wiring, in addition to some electrical contacts and moving parts that could get out of adjustment. High voltages in certain wiring could jump the insulation and not only cause short circuits but also endanger the operator, should the heater be repaired by someone not familiar with the principles and construction of the machine. Provisions for rapid servicing, after the original installation, were necessary in order to assure the prospective customer that in the event of his purchasing the heater he would not be subject to prolonged production delays because of breakdowns. Also, the customer's satisfaction in this instance was quite desirable, since there were several other possible users of similar machines in the same area who might be influenced by the first customer. Therefore the Midland officials undertook to formulate an erection and servicing policy for this and other Eastern customers.

### Preparatory Question

How could the Midland Company best install and service its customer in the East?

# CHAPTER XI

# CONTROL OF MATERIALS

Material should be recognized as one of the most important "M's" in manufacturing. It is a large determinant in forming the basis upon which men are hired to perform various operations in producing useful products. Large sums of money are required to procure, store, manage, process, and market it. Although the comparative value of materials in manufactured articles varies considerably with different types of articles, the economics of production efficiency requires in all cases that greater attention be focused by mangement on

1. Procurement.
   *a.* Quality.
   *b.* Quantity.
   *c.* Service.
   *d.* Price.
2. Receiving.
   *a.* Procedures.
   *b.* Records.
3. Testing.
   *a.* Meeting specifications and tolerances.
4. Storing.
   *a.* Raw.
   *b.* Processed.
   *c.* Subassemblies.
   *d.* Finished goods.
5. Materials handling.
   *a.* Organization.
   *b.* Cooperation with purchasing.
   *c.* Cost considerations.
   *d.* Intra-job handling.
6. Use.
   *a.* Maximum efficiency.
   *b.* Minimum scrap.
   *c.* Salvage and reclamation.

7. Serviceability.
   a. Research.
   b. Deterioration.
   c. Repairability.
8. Shipping and traffic.

**Procurement.** Well-managed companies recognize procurement of materials for use within the plant as a responsibility of the purchasing department, whether it be a department of a subsidiary plant from which purchase orders are passed through the general department of a large corporation, or whether it be the plant office that makes contacts direct with suppliers and vendors. In either case it is necessary for the purchasing department to know

1. What is required—with specifications and tolerances.
2. How much is required.
3. When it will be required.
4. What the market conditions are for maintaining supply.

Usually the first indication the purchasing department receives of materials being required is when it receives purchase-order requests to provide small quantities of certain materials, either from samples submitted, or according to specifications, to be used by the development department in experimentation with new products or for making changes in old ones. The information received under these circumstances is usually unsatisfactory for stocking the mill for production, as frequently several different kinds of material are tried before the best for the purpose is determined. Purchasing can be of great assistance at this point in supplying information on prices and availability of the supply to influence marginal decisions on selection.

**Specification Records.** Various means are used for the control and necessary distribution of information regarding specifications to the personnel of the plant who are responsible for production. Some of these means are

1. A standard sheet designed with specific provisions for specification information (see Fig. 24).

2. A set of cards composed of one card for each part of the product. The form is similar to the standard sheet mentioned in (1).

3. A tabulating card designed to have the same information punched as would be shown in writing on the "part cards" under (2).

Probably the most generally used procedure for keeping specifications in small plants and in some large ones is a printed form sheet

NAME OF PRODUCT________________ CODE________________

| Name of parts | Description of material | Gum coating or gage of gum | How applied | How cut | Die No. | Size range | No./pr | Remarks |
|---|---|---|---|---|---|---|---|---|
| Lining | 70/6 Med. Brn. Flc. | 4061 – .009 | E.M. Cal* | B.P.† | 2680 | *A* $2^2 - 3$ *B* $3^2 - 4$, etc. | 2 | Floured |
| Outsole | Roll Comp. 23 – 220 | Toe heal 160/210 | ......... | Wellman | W600 | Each die/size | 2 | |
| Buckles | 2240/28 | ........ | Tape loop | Purchased | ..... | ............. | 4 | |
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| | | | | | | | | |
| | | | | | | | | |

* Even-motion calender.
† Beam press.

FIG. 24. A specification sheet for a rubber-footwear plant.

of the loose-leaf type. The size of the sheet and the printed outline of information on it may be selected or designed to handle the specific requirements of the article it is to cover. It should have vertical and horizontal columns and lines in which may be listed every part required for the product, with a space for the raw material or purchased material from which each part is assembled, as well as for the partial assemblies that go to make up the part. Information as to size, gages, cutting, and preparatory information, and the number of pieces per unit should be provided.

Brief information of an instructional type for the preparatory processing of the parts is frequently included on the specification sheets because of the wide distribution they may have in the plant and the uses made of them by other departments, such as planning, methods, cost, etc.

Some companies prefer the flexibility of the "card-part" method of controlling specifications. The principal advantage is that paperwork changes in any part of the product can be made by removing the card representing the part and replacing it with a new one on which the revision has been made. This eliminates the necessity of revising an entire specifications sheet for the whole product.

Another advantage to be realized from the card procedure is the ease it affords in arranging specifications for a product that calls for parts or material that are standard for other products. This grouping facility is particularly advantageous for scheduling production in preparatory departments where change costs are an important factor. It helps to pull together all the same kind of material to be processed and provides longer runs with minimum changes and setups.

The tabulating-card plan is the most flexible, because it has all the advantages of the longhand card plan of (2) and also has certain mechanical advantages. For example, to change any part of the specification, the card for that part may be withdrawn from the set and a new one punched to show the revised specifications and substituted for the old one in the set. By running the set of cards through the tabulating machine, a sheet containing 70 lines of specifications can be printed in about one minute. By cutting a mimeograph stencil simultaneously with the printed sheet, a potential means of producing an unlimited number of copies is provided. Where the volume of specifications warrants the tabulating setup of equipment, this card system is very desirable because of the speed with which changes can be made and the potential volume of data represented. These advantages are particularly important in the tabulation of total quanti-

ties to be processed through the mill operations and in the subsequent scheduling of operations.

**Determination of Quantities.** Upon completion of the development, the final decision on standard material to be used forms the basis for the preparation of the material forecast. The sales department is required to make a forecast of the quantities of each product they expect to be able to sell during certain ensuing periods of time, such as seasons, quarters, months, or weeks. The sales forecast should logically follow in sequence the development and submission of samples of the products; however, there are instances where sales forecasts may precede or be made concurrently with the development work.

The production-control department correlates the sales forecast of products, the delivery requirements to be met, and the plant facilities in conjunction with current operating experiences, and determines the production schedule to be followed in satisfying all of the conditions. Sufficient information is now available for computing material requirements by quantities and time. The actual conversion of production schedules into material requirements may be a purchasing department or a production-control department function. Regardless of the responsibility, it is necessary that conversion factors for translating products into raw materials be established. The cost department factors from which the product material costs were built provide a good basis for the conversion factors. By adjusting them for scrap and processing losses experienced in development and trial production of samples, a satisfactory factor for use in determining material requirements for production may be established.

If the purchasing department is successful in placing the orders with suppliers who agree to meet the delivery requirements, production control is so advised and production plans are confirmed with the plant supervision and the sales-department executives.

**Selection of Samples.** Assuming that samples of the materials to be purchased were submitted by product development when the purchasing department was requested to shop for suppliers, it is desirable to have them procure sample quantities of the initial runs made by the suppliers as soon as possible. These sample quantities of commercial runs may be advantageously used for verifying quality standards and making trial runs prior to volume scheduling, in anticipation of processing difficulties to be encountered. Theoretically this may appear superfluous, but experience has proved in too many cases that shop practice on volume production with commercial materials does not exactly duplicate development practice with sample

Form 762

RECEIVING SLIP

B 642500

From__________

Purchase order No.__________ N. Y. order No.__________ Date__________

Shipped from__________ Via__________

F.O.B.__________ Car initial and No.__________ Production No.__________ Rate__________

| Description and special marks | Gross weight | Quantity | Unit | Unit price | Value |
|---|---|---|---|---|---|
| | | | | | |
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| | | | | | |
| | | | | | |

Received by__________ Delivered to__________ Freight__________

Building__________ Section__________ Bin__________ Entered on bin tag by__________

Class of stores__________ Entered on stores record by__________ Total__________

Fig. 25.

materials. This insurance to purchasing on the materials ordered and to production control in support of their planned production is well worth the effort.

As commercial deliveries start arriving from suppliers, it is good practice to inspect all shipments for correct invoicing, but it is likewise important to check the quality for uniform specifications. Some materials may be of such a nature that complete inspection should be made, while on others sample inspections may prove sufficient.

From a production-scheduling standpoint, only those materials that pass inspection are important, because only they may be used for production. However, it is customary to receive and accept into stores all shipments made against the purchase order, and adjust for rejections subsequently.

**Receiving-room Procedure.** The procedure for receiving materials into the plant includes, in addition to the physical handling, the proper records for doing the accounting. When purchase orders are sent to suppliers, a copy is sent to the receiving department of the plant, where it is filed by a PO number, vendor name, commodity, expected delivery date, or in some other preferred manner. The purpose is to have a record of anticipated deliveries against which incoming shipments may be checked as they are received and from which receiving slips may be originated and sent to the interested parties in the plant. The copy sent to production control informs them of the quantity and kind received and available in stores. The stores-department copy provides some of the data with which the balance-of-stores records are maintained—that portion pertaining to the On Order, On Hand, and Balance columns.[1] The accounting-department copy provides information relative to accounts payable that will be forthcoming. Each copy of the receiving slip performs an equally important function at its respective destination.

**Material Testing—From a Control Standpoint.** Various means are employed for determining the suitability of materials used in manufacturing. The specific tests to which they are subjected are determined by the kind of materials and the uses they are to serve in the product. Color may be the important consideration of a material for one product, whereas strength and durability may be the major requisite of the same material when used in other products. From a control standpoint the important thing is to have the proper test specifications for the particular job, which will insure that the materials provided are satisfactory, so that production schedules may be

[1] See Fig. 27.

met and standard quality products produced.[1] The supply phase of material testing is mainly concerned with the assurance that material in stores, against which production schedules have been planned, has been tested and is suitable for use.

Article

Location: Bldg. Sec. Bin No.

Max. Min. Unit

| Date | Rec. slip or req. No. | Received | Issued | Balance |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

USE REVERSE SIDE
When this tag is filled, transfer balance to new tag, and forward this tag to selective check clerk.

FIG. 26. Bin tag.

**Bin-tag Procedure.** As items are received into stores, checked against purchase orders, and reported on receiving tickets to those concerned, another important record of control is the *bin tag*. This record is kept at the storage area and consists of a separate tag or card for each different article stored. Every transaction involving the

[1] Material testing will be discussed more fully in Chap. XIII.

specific article is recorded on the card, shown in Fig. 26. Entries are made each time a shipment is received and for each issue of the article in fulfillment of a requisition. Any returns made to the bin, whether from overordering or cancellations as well as removals caused by rejections, are recorded. After each entry a new balance is established, which is the main purpose of the tag; to show the quantity

BALANCE OF STORES RECORD

DESCRIPTION: 8¾-inch brown-string automatic fastener

| *A* | | | *B* | | | *C* | | | *D* | |
|---|---|---|---|---|---|---|---|---|---|---|
| On order | | | On hand | | | Apportioned | | | Available | |
| Order No. | Amount | Order No. | Order No. | Amount | Order No. | Order No. | Amount | Order No. | Order No. | Amount |
| 2640 | 500 | | 2640 | 500 | | 10 | 200 | | | 500 |
| 2670 | 1500 | | | 200 | 10 | 11 | 150 | | | 1500 |
| | 2000 | | | 300 | | | 350 | | | 2000 |
| | 500 | 2640 | | 150 | 11 | | 200 | 10 | 10 | 200 |
| | 1500 | | | 150 | | | 150 | | | 1800 |
| | | | | | | | 150 | 11 | 11 | 150 |
| | | | | | | | 0 | | | 1650 |
| | | | | | | 14 | 50 | | 14 | 50 |
| | | | | | | | | | | 1600 |
| | | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Proof: $A + B$ must equal $C + D$ if entries are correct.

FIG. 27.

on hand at all times. By noting the quantity on hand on receiving slips and issues as they are sent through, the stores-records clerks are able to check the correctness of their records and maintain better information for production scheduling.

**Stores Records.** The balance-of-stores records, those important management aids, comprising a separate card or sheet for each material used in the plant, are subject to numerous entries if they are to perform their function properly. The object is for them to give a complete picture of the status of the material they cover. To ac-

complish this objective it is necessary to enter on them the data from purchase orders placed with suppliers, receiving slips of shipments delivered by suppliers, adjustments of overages and shortages received, adjustments for rejections made by raw materials inspection, requisitions received from the plant, and issues of materials made against them.

The accuracy of the balance-of-stores-card information is dependent on the precision with which all supplementary reports such as purchase requisitions and orders, stores requisitions and issues, receiving tickets, and finally the clerical work of making the entries are performed and transferred to the balance-of-stores card. The On Order column of the balance-of-stores record should list every purchase order by number and quantity that has been placed with suppliers of the article. The end figure is the total amount still on order. As deliveries are received and the receiving tickets sent to the balance-of-stores record clerk, he deducts the amount ordered from the On Order column total and adds the actual amount as shown by the receiving ticket to the On Hand column total. When the amount received is greater or less than the amount ordered, the difference is added or deducted in the Available column.

In the On Hand column the actual amount received from suppliers is added against each purchase order as shown on the receiving ticket. The actual amount issued for processing as shown on the Stores Issue ticket is deducted.

The Apportioned column lists the amount required and set aside for each order that has been planned for processing, but on which none of the particular material has been actually issued. The end figure is the total amount set aside for all the orders on which the issues have not been made. When the quantity is actually issued for an order as shown by the Stores-issue ticket, the amount apportioned for the order is deducted from the Apportioned column total and also from the On Hand column total.

The Available column shows the amount that can be apportioned for future orders or the balance after all orders being processed at the time have been provided for. The Available total includes the amounts on order from suppliers. Therefore, to obtain the real net quantity available at any time, the total of In Transit and unfilled purchase orders would be deducted from the total shown.

While stores records are generally considered in connection with raw materials, they may be designed to play an equally important part in the control of processed materials, subassemblies, and finished goods.

Requisitions have two general uses in manufacturing:

1. The purchase requisition.
2. The stores requisition.

The purchase requisition may originate from supervision in any part of the plant but usually originates with the storekeeper. It is a formal request for the purchasing department to order the particular commodity listed. Different companies require their own particular types of approvals, and frequently the estimated amount of money to be spent determines the approvals to be obtained before a purchase order to a supplier is originated by the purchasing agent.

The stores requisition may originate from any individual in the plant who has reason to obtain from the stores department any of the supplies in stock. It is customary to require supervisory written approval of each requisition made for supplies.

The number of copies to be made of purchase requisitions and stores requisitions is usually determined by the requirements of the particular company. The forms used are usually in pads so that carbon copies are easily made. Illustrations of requisition forms in use are shown in Figs. 28 and 29.

Purchasing is the actual preparation of a written order to be sent to the supplier of the particular commodity to be obtained. The form used for the purpose is the purchase order. Several copies of a purchase order may be prepared; the exact number is usually determined by the internal copy requirements of the company originating the order and to some extent by the number of copies required by the supplier with whom the order is placed. Each order is numbered to provide a means of identification in transferring the information to supplementary records and to facilitate correspondence that may be necessary in connection with it.

It is a responsibility of the purchasing agent and his assistants to establish contacts with reputable suppliers so that emergency requirements can be obtained and so that satisfactory sources of supply as regards quantity and quality will be maintained under abnormal conditions such as were created by the Federal defense program.

**Storing Materials.** The adequate supply and limited surplus referred to earlier are important considerations in the proper storage of materials. Storage space is always a problem in manufacturing. Obviously, the less there is to store, the better the job can be done. Probably of greatest importance is the accessibility of the storage to the point of use, assuming, of course, that moisture, temperature, and lighting are satisfactory. Storage technique varies with the materials to be stored. Bulk storage, which is perfectly satisfactory for fuel,

Form 766 Rev. 5-39

**REQUISITION ON STORES** | Date | No.

| Deliver to | To be used for | | | | Charge to | | | |
|---|---|---|---|---|---|---|---|---|
| | | Dept. | Bldg. | Floor | Acct. No. | P.O. No. | Eng. No. | Job No. |

| Quantity wanted | Unit | Description | Quantity issued | Unit | Unit price | Total value | Balance on bin tag | Location in stores |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
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| | | | | | | | | |
| | | | | | | | | |

Issued by________ Approved by________ Received by________ Delivered by________

FIG. 28.

Form 769 Rev. NOTE: In making out this requisition, never put items bought from different concerns on the same sheet. If in doubt, make out separate requisition.

P. O. No.______

Order placed with______ PURCHASE REQUISITION NO.______

Date______

Deliver to______ Wanted______

Account______ Wanted for______

Ship to______ Terms______

Via______ F.O.B.______

| Quantity to buy | Description |
|---|---|
| | |

Approved______ Storekeeper______

FIG. 29.

scrap metals, and the like, can be most unsatisfactory for materials requiring ventilation or light, or possessing pressing hazards. It is necessary, therefore, to analyze the situation and arrange to safeguard restrictions and peculiarities.

There are some principles, however, that may be stated for general application. For example, in considering accessibility provision should be made for adding to storage without handicapping the possibilities of using the oldest first. Where it is important to consume specific lots or groups in sequence, such as matching shades with minimum variations as required in textile materials, both storage and withdrawals should be facilitated. The normal incentive wage systems do not provide for sorting and selecting when applied to truckers and bull gangs, and frequently the most accessible stores are delivered when the harder to locate or inaccessible lots should be issued first. This merely illustrates the importance of planning and supervising storage to minimize the hazards of improper issuing.

**Storing Process Materials.** The storage principles stated apply to both raw and in-process materials. However, there are in-process materials in continuous-flow manufacture that require only temporary storage between operations. This type of storage represents the *controlled banks* explained in Chap. VII. Such material is generally stored with the object of being easily moved, preferably on wheeled trucks, lift platforms, or gravity conveyors, between the operations.

In job-order manufacture the customary storage, stores record, requisitions, and issuing procedures may be used, but a preferable method with some manufacturers is to accumulate all materials—raw, semiprocessed, and finished—in a separate location until sufficient, or all, are available for final assembly. This procedure obviously precludes the necessity of earmarking specific quantities in general stores for certain job orders.

**Finished Goods.** As materials reach the finished-goods stage, they may comprise a product having general consumer utility value, such as an article of clothing, a cooking utensil, a washing machine, radio, or automobile. They may also be yard goods from which the clothing is made, sheet metal for the cooking utensil, or the motor, gears, tubes, tires, and batteries of the washing machine, radio, and automobile. In short, the finished goods of one manufacturer may be the raw materials or subassemblies of another. From a strict material-control standpoint, the amounts assembled into the products that are delivered to the customer to fill his order represent the highest value the material attains during the production process. The raw

material purchased for the production of it involves some scrap loss which must be absorbed in the cost, and all of the labor and burden or overhead charges required to convert it from the raw stage into a finished product are added during the process. From an economic standpoint, therefore, the control procedures for finished goods deserve special attention. The utmost care should be exercised in accounting for all finished goods as they pass into the warehouse for storage or shipment to customers. Depreciation, deterioration, and obsolescence losses should be guarded against by prompt shipments which provide the medium for converting the raw materials, labor, and equipment back into cash.

Various types of records peculiar to the product and plant are used for controlling finished goods in transit to, and while stored in, warehouses. A stores record patterned after the form used for raw-material stores as shown in Fig. 27 may be used effectively as follows: The On Order column will show the shop orders scheduled and in process in the plant. Entries in the On Hand column are made as in-process *shop orders* become finished goods and are moved from the assembly into the warehouses. The Apportioned or Allocation column would show the customers' orders to be filled from finished stock already in the warehouse or from stock being processed. The Balance or Available column, as used for raw-material stores, would show the quantity against which no commitments have been made— the amount available for new orders when received.

**Organization for Materials Handling.** An important phase of the material-control problem in industry, which usually does not receive its fair share of consideration as an element of cost, is the physical handling. It has appeared to be a generally accepted conclusion that the responsibility for handling materials naturally belonged to an assistant of the purchasing department or a traffic manager who may not be recognized in the top line of supervision. In view of the amount of handling that materials require from the time they are unloaded at the plant platforms until they are ultimately routed into commercial channels for transportation to consumers, one must realize the tremendous exposure to increased costs—from unloading platforms to storage, out of stores into process, rehandling through various processes into final assembly, and warehouse handling as finished goods. The question very logically arises whether an assistant purchasing man or a subordinate traffic man is the best selection to supervise such an extensive and important element in the process. The purchasing function normally covers material only in its raw form and the greatest

amount of handling expended on materials is generally after it has passed from stores into process. The traffic function is normally confined to incoming raw materials and outgoing finished goods. Analysis of both these functions indicates adequate coverage of the extremes and very weak coverage of the in-between or process handling. It is therefore logical to conclude that better coverage of the over-all job is necessary and probably best provided by the creation of a new post in the top-line organization, to be known as a physical-handling manager. The duties of this office would comprise all phases of material handling from the receipt of raw materials to the shipment of finished goods and would be on the same plane with managers of other functional departments such as industrial engineering, product development, industrial relations, production control, mechanical, and laboratory. In this capacity the physical-handling manager would report to the works manager and would have cooperative responsibilities with other functional and production executives. The responsibility for material-handling procedures during process would require very close cooperation with the production-control and methods departments, since agreement would be necessary on whether conveyor, lift truck, or some other means would be used for the interoperation handling. Likewise, the exposure to damage by the handling procedures adopted would have to be analyzed in conjunction with the production and quality departments.

**Cooperation with Purchasing.** With responsibility for material handling under the physical-handling manager and raw-material stores under purchasing, the problem of handling "into" and "from" stores would require considerable cooperation, involving also the kind of storage facilities provided. Certainly any qualified physical-handling manager would be aware of the tremendous advantages to be realized from the use of pallets or the fork-truck-pallet combination for efficient and economical materials handling. The United States Army's experience during the war, when they so advantageously used thousands of fork-lift trucks and millions of pallets for the greatest material-handling task known to date, and by which they achieved an estimated displacement of 25,000 laborers and reduced the use of storage facilities by approximately 40,000,000 square feet, is sufficient proof of the importance of analyzing their application to material storage and handling problems.

**Cost Considerations of Materials Handling.** While it is generally recognized and agreed that processing motions applied to materials should add value to the materials in that they are formed into products,

the fact that handling motions add only to cost is not so generally recognized. Consequently, greater interest in the analysis of handling motions must be instilled to keep this element of cost under control. The ideal materials-handling system is one which consists of the fewest possible motions and makes each required motion accomplish the largest possible unit of work.

The following comparison illustrates advantages to be derived from the better way of handling the job. The problem is to move 1,000 cartons 200 feet and warehouse them. One way is to do it by hand, a carton at a time, by which method a laborer can pile 200 cartons an hour and carry them at a rate of 200 feet per minute. This would require five hours to pile the quantity, while 33.3 hours would be required for walking to and from the location: a total of 38.3 hours. If a five-carton-capacity hand truck were used, the travel time would be reduced to one-fifth, or 6.6 hours, while the double piling to truck and then to location would be 10 hours, or a total of 16.6 hours to do the job. If a larger 20-carton truck were used, the travel time would be reduced to 1.66 hours, while the piling time remains at 10 hours, or a total of 11.66 hours. Obviously the distance to be covered, involving travel time, offers the advantages of combining pieces into larger loads for economy; or, generally speaking, the larger the load within the limits of facilities, the greater the savings. It is only when travel time is less than piling time that the hand method—one carton at a time—is more efficient. When piling and travel times are equal, the method is optional. From the above illustration the advantages of pallet- and fork-truck handling, whereby the combined load is made at the source and subsequently moved intact, are obvious.[1]

**Intra-job Handling.** On the theory that men spontaneously and by nature are happier when working in groups, and that groups properly organized represent the most efficient method of production, the orthodox assembly line is being attacked from many quarters as less efficient on many operations. The attacks are aimed at the type of assembly in which each elementary motion is performed by a separate worker instead of a single-purpose machine tool. The contention is that when people are used to performing the operations, better results may be obtained by having each worker perform a sequence of motions and apply the group method to the job. This procedure automatically creates the need for the best handling of materials, parts, and subassemblies between the group operations.

[1] Data for the above illustration taken from "What's New in Materials Handling," by John D. Sheahan, American Management Association Production Series, No. 173.

**Shipping and Traffic.** Under the physical-handling-manager type of organization, the paper and records portion of the job would be a responsibility of the shipping foreman, who would supervise the selection of items from stock to be applied against the orders he was authorized to fill. The type of products to be handled would largely determine the part the physical-handling manager would play in the shipping and traffic departments. It is logical to have public-carrier traffic routings determined by a clerk on the shipping department staff and also by stock clerks who would make the physical withdrawals from warehouse stocks to fill orders for small, easily handled products. In the case of large, heavy articles, a means of labeling or marking the items to be withdrawn from the warehouse should be devised, and then the actual handling might be done by the physical-handling manager's crew. The shipping foreman's contacts would be split between the order and sales departments—whichever is responsible for the finished-goods inventory and shipment—and the physical-handling manager in transporting the finished-goods stock after being applied to orders.

**Procurement and Storage of Material for Job-order Manufacture.** The foregoing description of material procurement and storage applies in principle to both continuous manufacture and to job-order manufacture. There are some points in the latter that require special consideration.

First we shall consider the basic distinction between the two forms of manufacture. Tennis shoes, for example, are made in large lot orders for stock. Once a style or series of styles has been decided on and the probable consumer-market requirements forecast, materials can be ordered to specifications and delivery requirements laid down by the planning and control department. Tennis shoes are consumer goods, and in the same classification are radios, dishes, ready-made clothing, etc.

But the equipment in the plant in which the tennis shoes are manufactured is a part of the capital account of the manufacturer and has been built in the plant of a manufacturer in the capital-goods industry. For example, let us consider a Banbury mixer, which is a machine used to break down chunks of crude rubber and to mix the various chemicals used as accelerators with the rubber. Other processes follow, and eventually what was once crude rubber emerges as the sole of a tennis shoe. This Banbury mixer will be used in the production of thousands of pairs of tennis shoes and other rubber footwear and will last for years, with ordinary maintenance and running repairs.

Thus the market for these machines is obviously limited and unpredictable. Therefore they can be made to customer's order only and are made in a plant run on the job-order production system.

From the foregoing it naturally follows that material, with the exception of basic raw materials such as pig iron and coke, cannot be kept in stock by the machinery manufacturer without carrying an expensive inventory, the liquidation of which could not be accurately determined. Furthermore, the customer has definite delivery requirements that are based on his plans for plant expansion or on replacement of existing equipment. We must bear in mind the fact that the machine is built on the customer's order only and that all purchased material must be received according to a schedule originated by the planning and control department.

*Typical Procedure.* The typical purchasing procedure in a job-order manufacturing plant follows: The bill of material, as it is often called, is issued by the engineering department and lists every part required in the building of the order, including all bolts, nuts, studs, and small parts. Parts that are to be purchased as either raw, semifinished, or finished material are marked with the symbol *P* or *PU*. The purchasing department then purchases this material, embodying in the purchase order any detailed technical specifications, the inspection requirements to be met by the supplier, the date by which the material covered by the order must be at the purchaser's plant, and, of course, the price that has been quoted or agreed to by the supplier.

Copies of this purchase order are sent to the receiving department and to the material-inspection department or to whatever department is designated to inspect incoming purchased material. The receiving department records the receipt of the material ordered, notifying the purchasing department after receiving a satisfactory release from the material-inspection department. This releases the supplier's invoice for payment. At the same time the production-control department is notified that the material has been received and is ready for processing. This is noted on the production-control records.

The received material is placed on the stores-department records and is withdrawn only on requisition in a way similar to that described earlier in this chapter.

*Special Consideration.* It is thus obvious that, in the main, the routine procedure for purchasing and storing material does not differ widely from that previously described. However, this important difference must be borne in mind—in job-order manufacture there is usually no storeroom stock of materials to draw from. The material

necessary for the manufacture of the customer's order is usually purchased especially for that order. It is evident, therefore, than an extremely close follow-up of the material on order must be made by the purchasing department. The ability of the supplier to deliver by the required date must often be given primary consideration in the placement of an order. Price may be secondary.

This implies close cooperation between the planning and control department and the purchasing department, while in turn the planning and control department must expedite orders through the engineering department. In many cases, it is found necessary to issue preliminary orders to the purchasing department on certain items that ordinarily require a fairly long time to obtain from the supplier. Enough information is embodied in this preliminary order to enable the purchasing department to make the commitment with the supplier and thus obtain as favorable a position as possible on the supplier's manufacturing schedule. Exact details and specifications follow at a later date when finally established by the engineering department. This procedure is essential in times of great industrial activity and a rising market.

Again, during such times certain standard materials may become difficult to obtain, and it may become necessary for the purchasing department to develop new sources of supply. If substitute materials must be used, basic specifications should be determined by the engineering department. The purchasing department should never take upon itself the initial responsibility for such substitution.

*Shipping.* The shipping of large units, such as some products of the heavy-machinery industry, presents transportation problems very different from, and more difficult than those encountered in the shipment of consumer goods. Special well cars are often used. Because of the size of some units, shipments are sometimes routed over roundabout railroad lines that afford the necessary clearance over the loaded car. This requires expert knowledge on the part of the traffic department and close contact and cooperation with the railroads that will handle the shipment. As an instance of what is sometimes encountered, a large steel casting was transported to the plant of a heavy-machinery manufacturer. The transportation of this casting presented a problem for the railroads, and extreme care was used all along the way. For example, investigation proved that there was only 2½-inch clearance under a highway bridge over the single railroad entrance to the plant. This merely illustrates the necessity for careful planning and investigation in the routing of shipments. The traffic department

is constantly called on to trace and expedite incoming shipments of material. This plays an important part in the control of production.

### CASE 13. CONTROL OF FABRIC MATERIALS

*The New England Garment Company.*[1] This concern manufactures a medium-priced line of men's, boys', and youths' suits which are sold through a chain of company-owned retail stores. The materials they use in their products are mainly the yardage fabrics required for the outside and linings of their garments. They are confronted with material-control problems of matching cloth for the outer garments and issuing lining fabrics for the interiors. The outer fabrics are identical in weave, texture, and design, but occasionally the base color has slight variations in shade which will be evident throughout a roll. The lining materials are received from vendors in 1,200- to 1,500-yard rolls, whereas issues into plant processing may require 200 or 300 yards to be issued at a time. The issues into the plant may be requisitioned twice or oftener during a week. How should the stores of the outer fabric be controlled to minimize the effect of too great variation in the shade of parts being stitched side by side in the finished garment, which would result in an inferior grade of suit being produced?

In controlling the lining materials there are several problems, such as: What procedure would you recommend for assurance that the invoiced yards are in the roll when received? Would it be advisable to take a large roll from storage and measure the requisitioned yardage each time an issue is to be made? Would it be advisable to issue the whole roll and set up supplementary stores records to write off the total yardage as additional requisitions are received? What effect do you think the latter procedure would have on the effectiveness of your balance-of-stores records? What would you do if you decided that measuring the roll as received required too much work, and then discovered that your partial issues totaled less yardage than the company had paid for?

### CASE 14. ORGANIZATION AND OPERATION OF THE PURCHASING FUNCTION

*Superior Stampings, Inc.*[1] Superior Stampings, Inc., recently engaged the services of an experienced management engineer to improve the efficiency of its production methods. The concern, an old and well-known establishment located in the Midwest, originally made harness hardware, but with the passing of the horse its line

[1] Name fictitious.

changed to small novelty hardware and ornamental metal products used on wearing apparel. The concern, over a period of the last thirty years, has expanded considerably in size until it now employs well over 1,000 people, but its manufacturing processes and methods in general have remained about the same. However, the president of the company hoped that the new engineer would make changes to bring about a modernizing of the concern, and make it better able to meet the influx of emergency war business.

During a preliminary survey, the engineer found some interesting conditions in the purchasing department and decided to review the operation of that department first. He found that the man who bore the title of purchasing agent was about sixty years of age and had occupied that position for over thirty years. Years ago, when the company was small, he had carried on his purchasing duties on a rather informal basis, and as a result few formal records had been kept. Even now, with an expanded department necessitated by the increased size of the concern, the records maintained are not entirely complete. For example, the engineer was unable to find a complete record of vendors and prices paid on orders placed during the past few years. When the purchasing agent was questioned about this, he grew rather touchy on the subject and protested that the records he kept had always been found adequate in the past and he couldn't see any reason for changing now. But it was evident to the management engineer that many of the "records" were carried around in the purchasing agent's head.

Second, it came to light that the purchasing department was having difficulty in obtaining some of the sheet steel and brass required under the purchasing procedure in use. The department operated on a weekly purchasing budget that the treasurer, from years of experience, had determined should be 20 per cent of the sales dollar. At the end of each week the incoming sales orders were totaled, and the amount that the purchasing agent could spend for the next week was 20 per cent of that total. It was felt that this short-range and hand-to-mouth buying was necessary because of seasonal fluctuations and customer whims in the novelty business that made long-range forecasting of each individual material purchased extremely difficult.

Major items such as strip steel and brass in the various specifications, gages, and widths were carried to minimum inventory figures. The inventory records on these items were kept in the purchasing department, and it was difficult to tie in production planning with the records since they were not kept available to the production depart-

ment, and since no attempt was made to show the amount of material on hand and on order but not apportioned against shop orders already planned (see Fig. 30). Note that except for a running Balance on Hand, no Ordered, Planned, or Delivered balances are drawn off.

Purchased materials used by a single department in the manufacture of stock parts for assemblies were under the sole control of the foreman of the department concerned. These included steel and brass sizes used to make certain stampings always carried in stock pending the manufacture of other necessary parts to complete the assembly. The foreman alone requisitioned this material, and the system he used and the size of the inventory maintained were left to his discretion.

The weekly purchasing budget prevented the purchasing agent in many cases from ordering in large quantities to take advantage of price differentials. For example, when brass of a certain size and kind was ordered, the purchasing budget for that week might permit the ordering of only 25,000 pounds of that material, whereas if the concern ordered in 50,000-pound lots, a better unit price might be obtained. The only way in which the purchasing agent could take advantage of the price differential was to obtain the special permission of the president of the concern to buy the larger quantity.

The system that the purchasing agent used in ordering steel, although it worked well in normal times, was giving trouble under present conditions. Under the system, the purchasing agent gave the steel supplier a "letter of intention" two or three months in advance, stating how much of a particular kind and size of steel he estimated would be required by a specified date. This was not construed as a definite commitment on the part of the Superior Company but as a notification to the steel company to have that amount of steel ready for shipment at that time. On or within a few weeks of the date specified, the company would release a definite order to the steel company for immediate delivery. Depending on the volume of new sales orders and the size of the purchasing budget at that time, the steel order finally sent might or might not be for the same quantity as previously estimated. However, the Superior Company tried to keep the good will of the steel supplier by ordering as close as possible to the quantities noted in its advance letters and by ordering reasonably near the dates specified.

With the steel mills loaded to capacity, the letter-of-intention system was breaking down. The steel mills were no longer able to give immediate delivery on the orders sent out under the system, and

STOCK RECORD

ARTICLE: .0250 flat
SPEC: No. E4H
WIDTH: 6 inches

| Ordered | | | | Received | | | | | Apportioned | | | | | | Balance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Order No. | Vendor | Amount, pounds | Date rec'd. | Amount, pounds | Unit price | Total cost | Rec'g. memo No. | Reg. No. | Date wanted | Dept. No. | For art. No. | Amount, pounds | Date dlvr'd. | On hand, pounds |
| 3/15 | 106 | U.S.S. | 6,000 | 4/2 | 6375 | | | 159 | 686 | 6/15 | 21 | KR6 | 50 | | 6,740 |
| 4/15 | 301 | Beth. | 6,000 | | | | | | 761 | 5/10 | 16 | CP5 | 100 | 5/11 | 6,640 |
| | | | | | | | | | 981 | 5/31 | 02 | ZR6 | 64 | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

FIG. 30.

they were demanding definite orders several months in advance of the date required rather than a mere notification that orders were coming. This they said was necessary if they were to be able to meet the needs of the concern and maintain deliveries.

The management engineer, after investigating the foregoing conditions, felt that in order to conduct more accurate long-range forecasts and to make for a more progressive purchasing policy, the Superior Company must revamp several phases of its purchasing procedure.

### Preparatory Question

Imagine yourself to be the management engineer in this case, and recommend changes to provide the degree of purchasing control you feel is necessary. Explain what you expect to accomplish by each of your changes.

### CASE 15. INVENTORY CONTROL

*International Hardware Company.*[1] The International Hardware Company manufactures a wide line of builders' hardware—in fact, the line manufactured is so wide that it is causing a rather serious production and inventory problem. One of the members of the planning division of the company recently prepared a memorandum on the problem, in which the following facts were revealed:

The company currently manufactures 10,000 finished stock items and 20,000 semifinished part stock items. Of the 10,000 finished stock items, 500 items are seasonal and 1,000 are staple or *bread-and-butter* items, as they are called. In addition to the foregoing, every week orders are issued for an average of 2,000 special items (all different).

The wide line of items manufactured, both stock and special, appears to be a result of the attempt to meet the demand of the trade that all articles of hardware be available in several different materials and finishes. The following materials are commonly used in their manufacture:

Cast bronze.
Cast white bronze.
Cast brass.
Cast iron.
Sheet bronze.
Sheet brass.
Sheet steel.

[1] Name fictitious.

Wire goods. .
Glass (for knobs).
Aluminum (discontinued during the war).
Alloy metals.

The following finishes are offered:

Brass.
Old brass.
Bronze.
Old bronze.
Nickel.
Chrome.
Cadmium.
Japan.
Light nickel.
BB—black on iron or steel.

Officials of the company are of the opinion that the inventory cannot be simplified by discontinuing some items and increasing others. Trade demands and competition would not permit this, they believe. For instance, each section of the country has its favorite finishes. The East favors brass for its colonial designs, which are popular in that section. Bronze is the favorite in the Midwest, and the South and Southwest request light nickel and bronze.

The sales are divided into two main classifications:

1. Direct orders, which are classed as shelf hardware and are those items sold over the counter. In addition they include miscellaneous items sold to other manufacturers.

2. Contract orders, which are those sold for a definite building under construction.

Here again, depending on the class of trade, a variety of items is necessary. The government, for example, favors plain designs in its purchases. Schools, churches, hotels, and office buildings all require distinctive lines of hardware. In addition, manufacturers of fabricated homes and partitions desire special designs. Some of them even go so far as to design their own hardware, which, of course, requires special manufacture. Finally, in spite of the fact that a few sizes far outsell others, such items as screw eyes and hooks must be carried as a complete line in all sizes.

The problem results primarily from a desire on the part of the sales executives to be in a better position to give service to the customers. This can be made possible, they believe, only by carrying an adequate stock of all items likely to be required by customers.

The production and financial executives are opposed to increasing the inventory of items carried and point out the hazards and high cost resulting from carrying large inventories, as well as the difficulties of planning the manufacture of such a wide variety of items all carried to stock. They feel that the solution to the problem lies in a better sales forecast to reduce the number of stock items carried at any one time.

### Preparatory Question

What would you suggest that the International Hardware Company do to simplify its production and inventory problems without impairing its ability to give prompt service to customers?

# CHAPTER XII

# CLASSIFICATION AND IDENTIFICATION

The complexity of modern business requires some system of nomenclature of its products, materials, equipment, accounts, and departmental organization that will provide ease and efficiency in recording and conveying information essential to the production and distribution of the product. This requires first that some system of classification be established whereby products, accounts, equipment, etc., will be grouped according to certain similarities. Second, some means of identification must be provided that will symbolize these classifications.

**Classification.** A system of classification within industry follows basically the same principle used in the classified section of a telephone directory, wherein businesses, institutions, etc., are grouped under classification headings that are descriptive of their similarities. The purpose of this classification is to provide ease of reference. The same purpose may be fulfilled through the use of classifications within industries. For example, the following classification of functional departments is used by the United States Rubber Company in a section of its manual "Written Standard Practice," covering job analyses and half-hour schedules:

Accounting (include all departments reporting to control manager).
Factory manager.
Industrial relations.
Laboratory.
Mechanical.
Purchasing.
Production control.
Product development.
Planning.
Quality.
Sales-production coordination.

All jobs within each functional department in the foregoing illustration are listed and properly identified to provide ease of reference in the manual. This simple case serves to illustrate one of many uses of classifications within industry. Classification is the

basis for identification. Product specifications are written in terms of materials and parts classifications. Machines assigned to the production of a given order are designated in terms of the machine classifications of the company. Some system of classification is essential to all industries. In the small company it may follow very simple lines and may be needed only in certain phases of the work. In the large company it may spread throughout the organization, serving as an aid in the attempt toward coordination.

**Identification.** Descriptive information concerning classified parts, jobs, machines, personnel, etc., within a plant is usually too long for efficient use in writing and interpreting instructions for production and distribution. This has revealed the necessity for devising abbreviations or symbols that will identify classified items with the greatest possible simplicity. Simplification by the use of codes and symbols enables a large amount of information to be written in a relatively small amount of space. The form comprising a single sheet shown in Fig. 24 would need to be expanded to several pages or to a large sheet requiring special machinery for duplication and other office-machine operations, if abbreviations were not used.

The use of symbols and abbreviations is not new. For centuries such letters as M, denoting *thousand* in the Roman-numeral system, and B.C. for the term *before Christ* have been in use. The initials of our given names preceding the surname suffice to identify most of us. Nicknames are a type of symbol that usually covers the identification but often does not shorten it. It is common practice to use abbreviations in writing dates, such as 1/22/48 for Jan. 22, 1948. Industries frequently use numbers to identify work days within a given period.

One of the best examples of standard systems of identification is in use in libraries. Here books are catalogued according to both subject and author. Each classification is given an identification symbol, which is usually a combination of letters and numbers. Each book within a classification is further identified by additions to the general classification symbol under which it has been placed. For purposes of reference, this identification symbol is placed on the outside of the book and on the card representing the book in the catalogue file. Books and the cards that represent them are arranged on the shelves and in the files, respectively, according to their classifications. Through this system a book can quickly be located or replaced in its proper position.

There are many types of identification systems in use in industry. Each system has been constructed in terms of the needs of the partic-

ular industry that it serves. One interesting case will serve to show how a system of identification may develop with the growth of the company, changing when necessary in order to meet new needs. In the early days of the Chase Brass and Copper Company, a code system was devised for use in marking the mixture and metallic content on bars of brass or copper. Since there were only a very limited number of variations in the mixtures used, the code system could be relatively simple. The easiest way to mark a bar of brass was with an ordinary chisel, and the easiest mark to make with a chisel was a "straight" mark. Therefore |, ||, |||, |||| were each used to identify certain mixtures. These were referred to verbally as a one-mark mixture, two-mark mixture, etc. When a fifth variation arose, two new factors were considered: (1) space and (2) ease of recognition. Therefore, both horizontal and vertical marks were used (≡|≡|≡|≡), and four marks were enclosed in a rectangle ($\boxed{|\;\;|\;\;|\;\;|}$). Then came X, A, T, H, and other letters that could be made with straight marks. Double and triple letters were used, as in AA and TTT. As the variations increased with the growth of the company, letters and marks were combined as in V, $\underline{\text{V}}$, $\underline{\underline{\text{V}}}$. The marks in this particular case indicated the grade of zinc used in the mixture, V for third grade, $\underline{\text{V}}$ for second grade, and $\underline{\underline{\text{V}}}$ for first grade.

The continued increase in the number of variations in mixture finally exhausted the supply of straight-mark symbols. Someone thought of stamping the symbols on the bars with specially constructed tools. This made it possible to use curved lines and, consequently, all letters of the alphabet and any combination of numbers.

In recent years the company has adopted the use of tabulating equipment in compiling reports. To facilitate the use of this equipment, the symbols have been converted to numbers in the office. However, the mill still uses the original symbol, including the five- and four-mark squares that are so firmly established in the memory of the workmen and that therefore accomplish one of the intended purposes.

In general, there are two basic types of identification:

1. *Numerical*, where each item is identified by a number or a combination of numbers.

2. *Mnemonic*, where each item is identified by a combination of letters and numbers.

**Numerical Identification.** The numerical system of identification is the simplest form for use in a small plant or in a plant in which comparatively few items are to be classified. Separate numbers are

assigned to each item. Frequently an attempt is made to assign blocks of numbers to certain general classifications. For example, in identifying a comparatively small number of accounts, numbers 100 to 200 might be assigned to expense accounts, 200 to 300 for another class of accounts, etc. The division may be carried even further by assigning a different group of numbers to the expense accounts of each department or unit, thus facilitating the identification of accounts by organizational units. This may be accomplished also by prefixing the account symbol with the number of the department. Thus department 6 would have expense accounts 601, 602, 603, etc. These same general procedures may be used in assigning groups of numbers to parts, materials, equipment, etc.

In large manufacturing plants the numerical system may become so involved that the purpose of simplicity is lost. Lansburgh and Spriegel give an example of the complications that may result from attempting to use the numerical system in a large plant manufacturing diverse products: "The following symbol used by a paper-manufacturing plant is given: 801-2-3-0-5-16. This symbol was used to designate coupon bond paper, loft dried, second quality, glazed finish, weighing 16 pounds to a folio."[1] A number of this length is naturally very difficult to remember along with many others. The size of the number also greatly influences the probability of error through the transposition of digits within the number in copying from one form to another.

**Mnemonic Identification.** A mnemonic system of identification uses a combination of numbers and letters. The definition of the word *mnemonic* gives the key to the principal advantage of the system—*i.e.*, aiding the memory. The simplest type of coding under this system is through the direct use of initials, with a number to distinguish between different units of the same general description. For example, the following initials or first letters of the name of a machine might be used in code symbols:

L for lathes.

P for planers.

C for calenders.

D for drill presses.

Various combinations of numerical prefixes and suffixes used in conjunction with the letters further identify the machine. For example, L34 might identify lathe 4 in department 3. Building and

[1] Reprinted by permission from "Industrial Management" by Lansburgh and Spriegel, published by John Wiley & Sons, Inc.

floor identification throughout the plant might be controlled in a similar manner: B84 might identify the fourth floor in building 8.

Letters to identify different sizes of the same set of equipment are frequently used, since a letter is easily printed on the equipment in a conspicuous manner. This plan, applied to rubber-heel molds, might be as follows:

| Code Letter | Size |
|---|---|
| A | 2–2½ |
| B | 3–3½ |
| C | 4–4½ |
| D | 5–5½ |
| etc. | |

Thus the symbol 6C for molding equipment would mean mold 6, size 4 to 4½.

The mnemonic system of identification lends itself particularly well where the purpose is to classify and identify *all* items and organizational phases of a business. The organization of such a system involves first the complete analysis of the business to determine the divisions and logical groupings of the items to be classified and to be assigned identification numbers. The broad, general divisions are then broken down into the necessary subdivisions. Symbols, consisting of letters or numbers or a combination of both, are then assigned to each general division. The division symbol is supplemented by additional letters and numbers to identify the various subdivisions.

In the classification and identification of fabrics used in a manufacturing plant, the first division might be made according to the structure of the fabric—for example, A, knit; B, woven and miscellaneous. Division A might be assigned numbers 100 to 2,000 and division B, 2,000 to 5,000. A secondary classification is then made within each division; for example, "fancy cotton nets" might be assigned numbers 200 to 299 and "plain wool jersey," 900 to 999, since both are types of knit weave.

Continuing the classification of fabrics, division must be made in terms of color. If 99 basic colors are used by the company, these could be listed in any convenient order and numbered from 1 to 99. Variation within a basic color might then be identified by the use of letters. For example, if brown is identified by the number 2, ginger might be B2. Plaids, tricolors, and other special variations might be identified by the use of two or more letters or other specially assigned combinations.

To identify both the construction and the color of a fabric in a code symbol, using the foregoing explanation as a basis, the first group

of numerals in the code, three or four in number, would identify the construction. Separated from these by a line would follow the color symbol as shown in the following listing of fabrics:

| Code number | Vendor's style and description | Color |
|---|---|---|
| 1802-42 | 55-inch 13.5-ounces heavy wool net | Gray |
| 2003-B2 | ⅝-inch bias; center-fold brown, colonial binding | Ginger brown |
| 2021-H3 | ½-inch bias binding, cut $2\frac{1}{32}$ inch | Bermuda blue |
| 2411-87 | Tubular soft lace, 13 ounce. 23 picks, 2 ply | Yellow |
| 3385-AF | 1-inch Wright Fabric Co. Patt. 1094-g tricolor braid | Red, white, blue |

**The Error Hazard in the Use of Symbols.** The use of symbols in representing lengthy descriptions presents certain difficulties and hazards that lead to errors unless carefully controlled. The transposition of either letters or numbers in writing is a common mistake. In order to minimize the seriousness of a possible transposition, special attention must be given to the assignment of numbers and letters to the various classifications. For example, if all iron stove bolts have the letters ISB in their identifying symbol, transposed numbers in an order would still be in the general classification of iron stove bolts, even though the size of bolt was wrong. In this case the possibility of discovering the error through checking might permit adjustment without serious loss or might even be accepted by the purchaser as usable. However, if a simple error in transposition might completely change the division classification, the probability of serious loss and dissatisfaction would certainly increase.

It is sometimes possible for a manufacturing plant to use the same symbols in the identification of parts and materials as those used by the supplier of the parts and materials. This tends to eliminate errors that otherwise occur in recording and tends to simplify the identification in contacting the supplier. When the same code cannot be used, the logical alternative is to maintain a key sheet to be used in translating from the supplier code to the local factory code and vice versa.

The identification of finished products by code generally involves checking at some point of the order procedure to be assured that the code agrees with the description of the goods. The extent to which this checking may be necessary and advisable is subject to the same considerations as those applied to quality control described in Chap. XIII. The checking procedure can usually be combined with other clerical control operations without greatly adding to the burden.

For example, it may be necessary that orders for certain products be held out of production temporarily because of material or equipment delays that make production impossible at the present time. In such case these orders can be marked for holding at the same time that the clerk is checking the accuracy of the code symbols. The clerk would merely be instructed to withhold all orders for products carrying certain identification symbols. This is only one of many of the necessary clerical operations that can be combined with the checking of code symbols.

# CHAPTER XIII

# QUALITY CONTROL

**Objectives of Quality Control.** Quality control in its broadest sense concerns the systematic control of those variables in a manufacturing process which affect the excellence of the final product. Raw materials are all primarily derived from nature and hence vary in composition and characteristics. These materials on entering a manufacturing process are subjected to further variables in the form of men, machines, and manufacturing conditions. Men vary in skill and degree of carelessness; machines wear and tend to get out of adjustment with use; manufacturing conditions, including temperature, humidity, the composition of coolants, lubricants, etc., differ from day to day and from hour to hour. Thus the quality of the final product, unless controlled throughout the manufacturing process, is seldom very reliable.

The degree of quality that must be maintained, or in other words the extent to which these variables must be controlled, depends upon the degree of excellence desired in terms of the end use of the final product. For example, the quality of the casting that was your childhood piggy bank need not be as high as the quality of the journal-box casting that supports the wheel axle of the railroad car in which you ride. An imperfection in the former may be annoying to its owner, but failure of the latter can cause loss of life and property. Although not always involving such extremes, the end use of any product almost invariably determines its quality requirements.

In quality as in everything else there is a law of diminishing returns. As perfection is approached, costs rise to disproportionate heights. High quality not only means higher costs of manufacture but also requires that tighter controls be imposed on the manufacturing process, with the result that quantity output becomes more difficult. Thus, control of quality is closely interrelated with the control of quantity. In fact, no production-control system worthy of the name can be effective without it. In the light of the foregoing, the intelligent control of quality can be visualized as a production aid to management in keeping balanced that economic seesaw which finds quality and cost

both perched on one end and working in opposition to quantity of output sitting astride the other.

**Quality Control vs. Inspection.** Although the terms *quality control* and *inspection* are sometimes used loosely as synonymous, their meanings are quite different. Quality control is a program of management; inspection, a tool in that program. Through the *inspection* of materials, parts, and products and a separation of those lying within the standard from those which are not acceptable, the desired quality can be attained, but not necessarily the desired *quality control.* The latter is achieved only after the sources of defective material are located and corrected, after steps are taken to prevent recurrence of the defect, after the operating organization has achieved a quality-mindedness—in other words, after continuing quality is assured. In any enterprise, quality is based on a written and in some cases an unwritten law of what is right and what is wrong. Quality control sets the burglar alarm which prevents that law from being broken. Inspection, on the other hand, is simply the police dragnet that catches the burglar after the law has been broken. Quality control enlarges the production pile; inspection only enlarges the scrap pile.

**Setting Up of Standards and Specifications.** In the setting up of quality standards it should be recognized that there is no such thing as a perfect specimen. A blueprint may call for a 1-inch bar of steel, but no bar of steel is ever exactly 1 inch round throughout. Invariably it is out-of-round, tapered, thicker at one point than at another, and furthermore, no two bars are ever identical.

Machines are born from other machines and inherit the imperfections of their predecessors; they seldom can be mounted absolutely level; ways and guiding surfaces are never perfectly square. Moreover, bearings must have some play, moving parts always vibrate, and surfaces moving relative to each other invariably wear. Nature herself furnishes us with material that is not homogeneous throughout. Also, no instrument of measurement is perfect. All instruments so far devised involve moving parts, and the wearing, friction, and play between moving parts make an absolute consistency of readings impossible. Furthermore, there are human characteristics of the plant personnel that introduce additional variations. Muscular coordination, limitations of normal eyesight, fineness of touch, feel of the "mike" and other measuring devices—these are typical of the human variables in a process. It will be noted that all of the variables mentioned up to this point are inherent in the process, machines, materials, and employees. They are called *chance variables,* and while they can-

not be eliminated from a process unless the process itself is changed, they generally do exert a stable and predictable effect on the quality pattern of the product involved.

Quite different is another set of variation causes: *assignable variables.* These are not inherent in the process, hence, once they are discovered, steps can be taken to correct or eliminate them. They are generally erratic and exert an unpredictable effect on the product quality. An operator may not understand the task or objective assigned to him. He may fail to adhere to instructions. Perhaps an employee with poor eyesight is hired for a job requiring good eyesight. His attitude or attention to his work may not be properly directed. Through an error, material of the wrong specifications may be delivered to the manufacturing process. A machine that is not properly oiled may not operate freely. Or a machine that has not been properly maintained may be turning out inferior products. Such variables as these are assignable and, hence, upon discovery, controllable.

From the foregoing, we can recognize the impracticability of setting quality standards higher than can be maintained under the chance variables inherent in the available machines, measuring devices, materials, and man power. When all assignable causes of variation are eliminated and only chance causes are acting on the process, it is said to be *under control.* The band of acceptable quality as determined by the quality standards then, must be broad enough to encompass the quality pattern resulting from a process under control.

Quality standards are usually stated in terms of the ideal dimension or requirement with a permissible plus or minus variation. These plus or minus variations, known as *tolerances,* represent the permissible range of error or departure from the ideal dimension within which the part or product is acceptable. They are working standards that must represent a compromise between the minimum customer requirement for quality and the cost of manufacture as determined by the law of diminishing returns.

In general, standards should be reasonable, measurable, available, and understandable. The specification for a part, *finish all over,* is far from reasonable where several surfaces fit air and could obviously be left in their rough state. The specification that a part must be *oiled* is not measurable, nor is it completely understandable unless the answers to the questions "How?" and "With what material?" are appended. A part drawing that is not issued to all personnel concerned with the manufacture of that part can hardly be classed as available, and it encourages a dangerous reliance on pure memory.

Specifications and standards naturally start with raw materials. They specify the material, its composition, its form and shape, finish, preparation for shipment, etc. Regarding the finished part, the permissible tolerances granted in the specifications will determine to a great extent the number and kind of processes required on it. For example, if a $\frac{1}{10}$-inch tolerance is permissible, a sand-cast surface may be satisfactory. If $\frac{1}{100}$ inch is allowed, possibly a forged surface can be used. A tolerance of a few thousandths can often be maintained by automatic machining, but a tolerance of the magnitude of a few ten-thousandths requires a grinding operation. Finally, the standards of the final product—its finish, its operation, and its performance—must be set up to establish what the customer will accept.

To be usable, standards must remain static for a period of time. However, this does not preclude their revision as demands and manufacturing processes and methods change. As in setting up the original, the criterion for a change in a standard should be: Does the change result in the minimum quality desired, with proper regard for the cost of manufacturing to that standard?

The question of who sets up and maintains the standards is an important one. Best current practice dictates that the sales, design, and manufacturing departments should all participate in the setting up of the standards. Then it is up to the inspection department to enforce them. Some concerns have also turned over the erection of quality standards to the inspection department. This practice puts that department in the difficult and unfortunate position of becoming the judge, prosecutor, and jury in relationship to the work of the production department.

It is a common and justifiable criticism of some standards that they are not precise enough and that they admit of too much personal discretion. The wine industry, for example, still uses tasters to pass on the quality of wine. These tasters, although they never swallow the wine and continually refresh their mouths with bread, would be the first to admit that not only do different tasters disagree in their rating of several wines, but the same taster might rate them differently at different times. When a customer specifies that a ball bearing be "free-running but without any perceptible play when shaken by hand," that specification is subject to much personal fancy on the part of the inspectors as to just what bearings fall within it. However, the bearing industry has endeavored to educate users to specifications that involve a measurable play under certain specified artificial loads, so as to take the guesswork out of the standard. Similarly, ketchup,

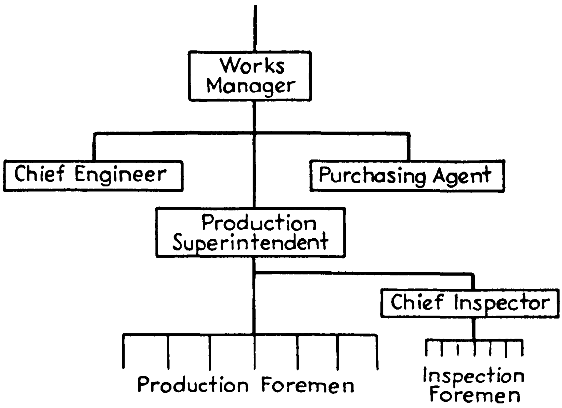
which might seem to be a product admitting of much personal discretion, is now graded by one leading manufacturer according to color, acidity, air content, and viscosity (tendency to spread)—all are measurable specifications for which definite tolerances can be set. The specification for viscosity is rather interesting. It involves the use of an inclined board on which different mixtures of ketchup are given an even start. The ketchup that stops between two given marks on the board is the one that eventually finds its way to the hash on your plate.

**Organization and Operation of an Inspection Department.** Depending on the size of the company and the importance of quality in the product, the inspection force may consist of only a few people or may range up to a large department or departments involving a high percentage of the total employees. One manufacturer of a high-quality product advertises that "One-fourth of Our Personnel Is Authorized to Say 'No,' " and the advertisement goes on to state that this large percentage of its employees is engaged in inspection work and is authorized to say "No" on any of the material submitted by the production men. The duties of inspectors may range from that of two men in a certain food plant whose entire time is spent catching and destroying cockroaches to that of the men who put new model automobiles through their paces over a Michigan proving ground.

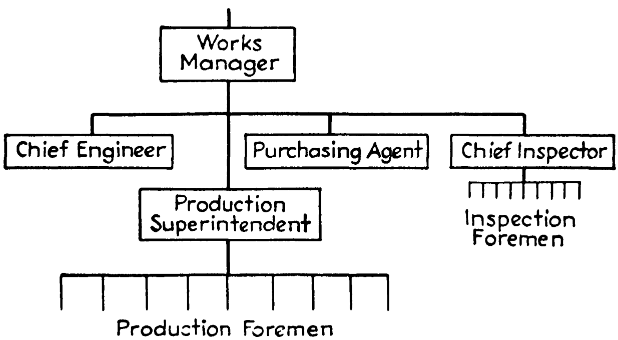
The inspection department is usually in charge of the chief inspector, who in turn reports to some individual who is sufficiently high up in the organization to make inspection a separate major function and who is able to offer impartial judgment. Some companies still fall into the error of placing their inspectors under the authority of an individual who is responsible for quantity. With this organizational setup there is always the tendency when trouble develops in the manufacturing processes or when the company is behind in its delivery schedules for this individual to override the judgment of his inspectors and pass an inferior product. The danger in this is twofold: not only does it undermine the morale of the inspection group but it encourages production workers under such circumstances to cut corners in their work if they think they can get away with it.

In general it may be stated that where inspection is not of prime importance, the inspection department in an organization should be just high enough up in the organization to be under an impartial authority. In many concerns, the chief inspector would be responsible to the production superintendent. However, where quality and hence inspection are of prime importance and figure greatly in company policy, the chief inspector should report directly to the works manager

and would possibly be on a par with the chief engineer and the purchasing agent. The inspection department may be functional to other departments, but its internal structure is usually line or line and staff with the final authority and discipline within the department resting in the hands of the chief inspector.




(a)




(b)

FIG. 31. (a) Usual location of inspection in an organization where quality is not of prime importance. (b) Usual location of inspection in an organization where quality is of prime importance.

The duties of an efficient inspection department well might include the following:

1. Performance of all inspection of production in every department.
2. Inspection of raw materials.
3. Inspection of chemical and heat-treating processes.
4. Inspection of tools, both purchased and company-made.
5. Control of all checking of gages and measuring devices, including authority to requisition such equipment.

6. Supervision of work allied with or incidental to inspection, as final washing operations, oiling and greasing, wrapping or packing.

7. Joint or even complete supervision of salvage work and the disposition of scrap to ensure that no defective work gets back into the productive flow.

As a chain is only as strong as its weakest link, so quality is only as good as the poorest inspector. An inspector of the type who recently passed an automobile gasoline tank so poorly welded that it leaked around the entire length of the joint does little to improve the reputation of the manufacturing company and, in fact, does not inspect very long for any company. It behooves any company to choose its inspectors carefully, and more and more companies are turning to job-analysis tests as a means of selecting individuals who have the necessary characteristics for making good inspectors.

The good inspector is one who carries out orders faithfully. He must possess a rather high degree of finger dexterity, should have a quick reaction time to enable him quickly to recognize a good or bad article and dispose of it in the proper receptacle. But, above all, he should have the ability to give his concentrated attention for extended periods of time on routine work, for the greater part of inspection work is of a routine nature. The fact that women frequently possess these qualities to a greater extent than do men makes them in many instances better inspectors. This has been proved repeatedly in recent years as the shortage of man power in war work led many companies to replace a great number of the male inspectors with girls.

It is of prime importance that the inspection department be able to cooperate with manufacturing departments and that inspectors as individuals get along well with the foremen and machine operators. Whenever trouble appears at any station, the first step is usually for the inspector or his immediate superior to take the matter up formally with the foreman of the department concerned. If the trouble can be corrected by the foreman, the matter is dropped then and there. But if, for example, the machine has become worn and certain parts must be replaced, the inspector may act as intermediary for the foreman in securing the necessary attention from the machine-tool and maintenance division. Or, if the trouble lies in poor working qualities of the particular lot of raw material, the inspector or his superior may take the matter to the engineering and receiving inspection departments for their consideration. Thus it can be recognized that quite often a good inspector must be a good diplomat.

The question of what method of payment should be used for inspectors has been a live one in recent years. While most companies pay their inspectors on a straight hourly or day rate, a number place them on some sort of wage-incentive plan based on quantity of work inspected. This usually takes the form of simple piecework. Where inspection is on a quantity-payment basis, steps invariably have to be taken to maintain control of quality. These usually consist of increased inspection supervision, or sometimes a picked crew of "inspection inspectors" who sample at random the work already passed by the regular inspectors. Some concerns even pay a premium to their packers for finding a rejectable article that has been passed by the regular inspectors.

The question of how best to overrule the inspectors often arises. Frequently a dimension on a particular part may "mike" or gage right on the maximum or minimum limit, and the inspector wonders whether or not to scrap the article. One possible and unfortunately all-too-frequent solution is for him to get the permission of his superior to broaden the tolerance to a fraction over or under the limit if the superior feels that probably the part is usable and is willing to take a chance on it rather than assign the part to the scrap heap. Although this slight broadening of tolerances may be permissible as far as the superior is concerned, this method of permitting routine inspectors to pass such questionable work can have but one effect on them, and that is to instill in them a disregard for exact adherence to any and all standards set up. A far better procedure from the standpoint of inspection morale would be for the inspector to be instructed to hold out questionable work, submit it to his superior or to some special and highly skilled inspector, and let him pass or reject each individual part on its own merits and thus personally assume the responsibility for any broadening of the limits.

**When to Inspect.** The decision as to when to inspect is an important one from a cost standpoint. Whereas some companies making a product where quality is not extremely important inspect only before shipping to the customer or before placing the product in stock, other companies making high-quality products place inspections after each operation. However, the more general practice is a compromise between these two extremes, and it becomes necessary to decide at just which points in the productive process to locate the inspection operations in order to achieve the most effective control at a minimum of cost.

In deciding when to inspect, several basic principles should be remembered.

1. Inspections should be placed at the source of variations. Tools wear, drills become dull, form-grinding wheels lose their form. Thus these are points at which some sort of periodic check is required to keep the part within the desired tolerance. It is a common occurrence to find setup men and piecework machine operators who, in an effort to increase the number of pieces per hour, set their machines so that a minimum of stock is removed while still operating within the given tolerance. In the case of external machining, for example, this would mean setting the machine to work as close as possible to the high tolerance limit. However, this practice is rather shortsighted, for as the tool wears slightly or shifts in the holder, the tolerance is exceeded and defective material results. Here, then, is an obvious point of inspection, and a good inspector making periodic checks at this point could insist that the machine be set to work at the low side of the tolerance, so that as wear and shifting take place the high limit is not immediately exceeded.

2. Inspections should be placed at points at which failure would be costly. For example, should the tool on a machine suddenly chip or should the part itself become cracked, the defect might cause a subsequent machine to jam. Hence a logical point of inspection would be just prior to the operation where the defect might cause the trouble.

3. Inspections should be placed so as to discover defective work that would affect a long series of subsequent operations. A heat-treating operation followed by a series of grinding operations would fall in this category. It is also well to bear in mind in this connection that the later in the process the defect is disclosed the more costly the rejection becomes.

4. A logical point of inspection is prior to an operation that would conceal a defect of a previous operation. Painting that covers up a surface defect or an assembly operation that hides a defective part are examples of this.

5. Inspections should occur when material is transferred from one department to another. Such inspections may take place just before one foreman is relieved of the responsibility for the material or immediately before the next foreman assumes that responsibility. This is an important rule, for it aids in the location of the source of defects and in fixing responsibility for them. Where work moves from one department to another, it is often possible to eliminate some clerical work by using one copy of the inspection ticket as the move ticket. Figure 32 shows such a ticket, made out as an original, with three carbon copies. The original is usually sent to the manufacturing department whose work is being inspected; the second to the production office to report

movement of material; the third is retained in the inspection department; and the fourth remains with the work and shows the next department to which the work is to be routed.

The question of when to inspect goods made for the government services is often set forth in the government specifications for such material. This is true whether the product is one sold directly to

| | | | Totals |
|---|---|---|---|
| Part No. | Article | Good pieces | |
| Operator No. | Type machine | Rejections (not fault of operator) | |
| Employee No. | Department No. | Rejections charged | |
| Inspection by: | Date | Amount inspected | |

| Reason for rejection | For correction | Scrap |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| Move | Total | Total |
| From Department | | |
| To Department | Moved by | Date |

FIG. 32. Combination move and inspection ticket.

the Army or Navy or is made by a subcontractor for a prime contractor supplying the military services. In either case, regulations usually require that Army or Navy inspectors be called to the vendor's plant or be stationed there permanently to inspect at strategic points in the process parts and products manufactured under government contract. Each article accepted or its container must be stamped with the service acceptance insignia before it may be shipped.

**Where to Inspect.** The inspection of raw materials may take place at one of two places: either at the plant of the vendor prior to shipment or at the purchaser's plant immediately upon receipt. Both methods are in common usage today. The metallurgical inspection of steel is frequently performed at the vendor's plant by a traveling representative of the purchasing company or by an independent commercial inspection concern hired for that service, the object being to discover defective material at its source and thus save the time and expense otherwise necessary to return this material to the vendor. On the other hand, the inspection of castings and similar articles in which form is the important requirement is usually performed at the plant of the purchaser.

With regard to the inspection of material in process, there is the question of floor vs. centralized inspection. Where floor inspection is in vogue, a roving inspector armed with the necessary micrometers, calipers, or gages periodically visits each machine and "spot-checks" the material coming off the machine. The advantage of this method is that it enables the inspector to single out a machine making defective work and assists the operator in correcting the machine before many defects have been made. In addition, it saves the time and cost of transporting the work to an inspection area. The centralized inspection method, on the other hand, requires that the material be routed to inspectors located in a centralized area or room. This arrangement offers better conditions for inspecting, less interference, better inspection supervision, and facilitates the control of the accuracy of inspection gages. It is used primarily for 100 per cent inspections or where complicated or intricate inspection devices are used. The disadvantage of centralized inspection is that it tends to disrupt the flow of production. Line production, however, offers the possibility of a rather effective compromise between these two methods. In such cases the inspectors can be given a fixed station in the production line, and their tempo can be geared to that of the production operations so that no retarding of production takes place.

Where inspection is centralized in a job-order shop, its location within the plant is an important factor. Not only should light and working conditions be considered, but the area should be located centrally with regard to the production operations or departments from which material is drawn. If several centralized inspection areas are located about the plant, it is important that the gage room (or rooms) serving them be located as centrally as possible to the areas served. Where inspectors are required to commute between

poorly placed inspection areas, it is a common occurrence for them to succumb to the "hoof-and-mouth disease," and not only does the efficiency of the inspection department suffer, but the efficiency of other workers who are thus encouraged into conversation is impaired.

Tools should be inspected at the tool crib periodically. Generally these inspections take place after the tool is made, sharpened, or repaired. Many concerns require that the first few pieces made on a machine after a setup be brought to the tool crib for inspection before the operator is permitted to start quantity manufacture. These pieces, if acceptable, are then returned to the operator for his use as samples. In addition to furnishing a check on the tools, this practice ensures that the machine is set up correctly, and subsequently aids in fixing the responsibility between the operator and the inspectors in the event that defective material later develops.

Best practice requires that finished products be inspected as near as possible to the wrapping or packing operations. Transportation for any distance of an inspected and unprotected product is dangerous business. Often, if the final inspection is simply visual, it can be combined with the wrapping or packing operation. Above all, final inspection should be so located and arranged as to make for the optimum speed of inspection and to minimize the delay of production schedules.

**How Much to Inspect.** In deciding how much to inspect, it should be remembered that inspection is a strictly nonproductive operation that adds nothing to the value of the product. Consequently, the answer to the question of "How much inspection?" is: the least amount that will accomplish the objective and furnish the control desired. Obviously work from an automatic screw machine, once the machine is set up, requires less inspection than that from a hand-operated turret lathe. Thus, whereas the turret-lathe material may require a complete or 100 per cent inspection, usually the work from the automatic machine needs only a "sample" inspection from time to time to ensure that the machine maintains its adjustment.

Certain precautions must be taken in sample inspection. The samples must be selected at random and preferably without the knowledge of the operator. Otherwise a not too honest operator is encouraged to see that the inspector gets only the good pieces and that the bad ones remain hidden in the bottom of the box. The sample or samples must be representative. Liquid mixtures and emulsions require special care that the components of the sample be of the same proportion as in the entire solution. Good metallurgical

inspection procedure dictates that samples from a steel billet, for example, be selected from the top, middle, and bottom of the billet. Tests on coal for heat-unit properties call for repeated quartering processes to obtain a representative mixture.

Usually final inspections call for a 100 per cent rather than a sample checkover. The final inspection is invariably visual, but frequently it may include a performance or operation test. Such a test, often called an *engineering inspection*, is very common with large installed or assembled products, such as large electric generators and motors. Similarly, each airplane motor (after assembly) undergoes a thorough "break-in" test, is torn down, examined part for part, and reassembled. All airplanes are put through a series of test flights and performances before being pronounced satisfactory. However, one interesting exception to the 100 per cent final inspection rule has to do with electric-light bulbs. As the prices of light bulbs have gone down, some manufacturers have reduced inspection costs by eliminating a complete inspection on certain bulbs, and their final inspection is performed by the ten-cent-store salesgirl who tests your lamp bulb before your own eyes as you make your purchase. By educating people to this practice, these manufacturers have eliminated some inspection costs without running the risk of selling the public defective lamp bulbs.

In connection with the problem of how much inspection is necessary, the question frequently arises as to how responsible the production foreman is for holding his workers to the desired quality standards. Usually, where the worker is on a piecework or other incentive basis, he is paid only for the good pieces he turns out. But this in itself is not sufficient to keep the waste to a minimum. Hence some other check usually is necessary. Some companies rely on the foreman to watch his operators carefully for poor work right at the machines. These concerns feel that unless the foreman is able to control the quality in his department, he is not the man for the job. Other companies feel that the foreman's prime duty is to see that the productive capacity of men and machines in his department is being used effectively and that to ask him to assume the added burden of becoming an inspector will only detract from his effectiveness. These companies assign roving inspectors to the control of quality at the machines.

Any program of quality control must recognize that some scrap is inevitable and that the higher the precision or quality required the greater must be the percentage of the material scrapped. Con-

sider, for example, the two extremes of the completely mechanized manufacture of tin cans on the one hand and—the ultimate in precision craftsmanship—the manufacture of airplane engines, on the other. With the former the only important requirement is, does the can leak? Thus tin cans are subjected to a 100 per cent final "pressure" inspection that reveals weak seams, poor soldering, imperfect sealing, etc. In spite of the complete mechanization, there are rejections, although they average only 2 cans in 10,000 or 0.02 per cent. Contrast with this the parts of an airplane engine, which are held to closer tolerances than are required in the average watch and which are, as the tool engineer of one of the engine manufacturers said recently, "handled like eggs—only more carefully." On such parts the machine rejections average 15 per cent. Thus high-quality manufacture takes its toll in parts that find their way to the scrap heap.

**Statistical Quality Control.** If experiments at the Midvale and Bethlehem steel companies initiated by F. W. Taylor once touched off the spark that flamed into the "scientific management movement," and if the bricklaying trade under the guidance of F. B. Gilbreth gave birth to the science of motion economy, so also may the engineering personnel of the Bell System (Bell Telephone Laboratories and Western Electric) under W. A. Shewhart take credit for breeding an equally important science: that of statistical quality control.

Statistical techniques making use of frequency curves (law of probability), arithmetic means (average), standard deviations, ranges and fraction defective are not new. However, the mathematical hypotheses and formulas incident to their application for controlling quality require a knowledge of statistics not possessed by most plant personnel. Thus not until recent years, when the statistics were reduced to workable tables, has this more systematic control technique found widespread acceptance in industry.

Statistical quality control can be directed toward a variety of objectives, and the exact technique employed depends upon what objective is sought. One technique, making use of what are known as *control charts*, aims at locating and correcting incipient trouble before rejections develop.[1] Control charts reveal when assignable variables exist and may point to causes for correction. They can be truly said to bring quality *under control.* They likewise indicate whether only chance variables are acting, thus revealing when the

[1] In one coffee plant, machines that fill the cans are controlled by this method. Samples are taken and weighed hourly. The weights are posted and watched closely so that the measuring equipment can be corrected before it goes so far off limits as to overfill or underfill cans.

process should be left alone and eliminating needless adjustments. The same charts can also be used for the intelligent judging of present quality against past performance. An allied charting arrangement helps to establish workable quality tolerances which the existing process is capable of producing and maintaining.

Other statistical techniques aim at a reduction of inspection costs through statistical sampling. Of course, under any plan of sampling inspection, statistical or empirical, some defective parts invariably will be passed. However, statistical sampling methods attempt to calculate the risk of this type assumed under possible sampling percentages and techniques so as to permit a selection of the procedure that furnishes the maximum protection with a minimum of inspection. Some parts and products require destructive or life tests, and statistical sampling is a "must" for ensuring a desired level of performance.[1]

A detailed treatment of the methods and procedures under which quality can be controlled statistically is beyond the scope of this book, and the reader is referred to some of the excellent texts dealing with this subject, a few of the better known being listed in the bibliography at the end of this volume. It is important to our purposes here, however, to note that during and since the Second World War industry has made greatly increased use of statistical techniques and is today finding them of tremendous help in achieving truly effective control of quality.

**Engineering of Inspection Methods.** The layout of inspection processes requires as much forethought and planning as that required for any of the productive operations. The layout should be such as to cause as little interruption to the smooth flow of production as possible. Material passed by the inspectors, going from one operation or department to the next, should proceed automatically with a minimum of handling and clerical routine. In this connection, conveyors are as applicable to inspection as to the productive operations. Material held aside for correction or rejection must also be provided for in the inspection layout so that its proper disposal can be effected. Whether or not the inspection area should be screened or even closed off depends on the conditions surrounding the area. It can be said, in general, that effective inspection requires an area free from dirt, excessive noise, and vibration. The concern that locates its Rockwell hardness testers and delicate chemical balances directly above some 25-ton presses can hardly expect to get good inspection results.

[1] The only sure way to test the performance of an electric fuse is to increase the amount of current until it blows. The strength of a weld is best determined by breaking it. The life of an electric-light bulb can only be checked by letting it burn itself out.

Motion-economy principles can very frequently be applied to inspection operations and layout to smooth out the material flow and reduce inspection cost. The design of the individual inspection bench and chair should permit the maximum ease and comfort of the inspector. A poorly designed inspection workplace is very often the cause of "4 o'clock fatigue." The bench area used by the inspector should be circular to conform rather well to the normal sweep of his extended arms so as to keep him from continually bending forward and reaching for a part or a gage. Where the parts inspected are small, suitable feeding devices can often be devised, or at least the parts can be placed within easy reach at all times by placing the container in a tilted position on the bench. Chutes or drop disposal devices are often the simplest means for the inspector to dispose of the parts. Two holes cut in the bench with chutes down to the respective disposal boxes permit the inspector to drop good pieces into one and rejects into the other.

Perhaps the most common and by far the most wasteful motion during inspection is that whereby the inspector uses one hand as a device for holding the part while using the other to manipulate the micrometer or gage. A hand used as a holding device does absolutely no effective work. Often this can be eliminated by providing the inspector with an automatic or even foot-operated holding device that leaves both hands free for productive work. With such a device frequently two pieces can be inspected where one was inspected before. Also, where both hands are free, symmetrical and rhythmical hand motions are permitted, and rhythm is one of the greatest time savers in any operation.

Repeated or continual inspection with micrometers is a slow and somewhat wasteful method. Usually these can be replaced by fixed-size "go" and "no-go" gages. Where such gages are used, the part to be acceptable must slip into the "go" gage but must not be of such size as to slip by the "no-go" gage. These gages are usually of three types: working gages for use by the operator in performing the operation on the part, inspection gages used in inspecting the part, and the master gages used in checking and keeping the inspection and working gages in proper order.

A common complaint of "go" and "no-go" gages is that they wear quickly and must be continually reset and replaced. Powder metallurgy has now furnished industry with special alloys that have long wear characteristics and can be used as inserts in gaging surfaces. Also, snap gages, plug gages, and similar devices made of tool steel

can, on becoming worn, be chrome-plated and the gaging surface reground to the proper dimension. Furthermore, a master gage that becomes too much worn for that purpose can then be repaired and used as a regular inspection gage, and an inspection gage, in turn, can be used as a working gage. Similarly, plug gages, which are a com-

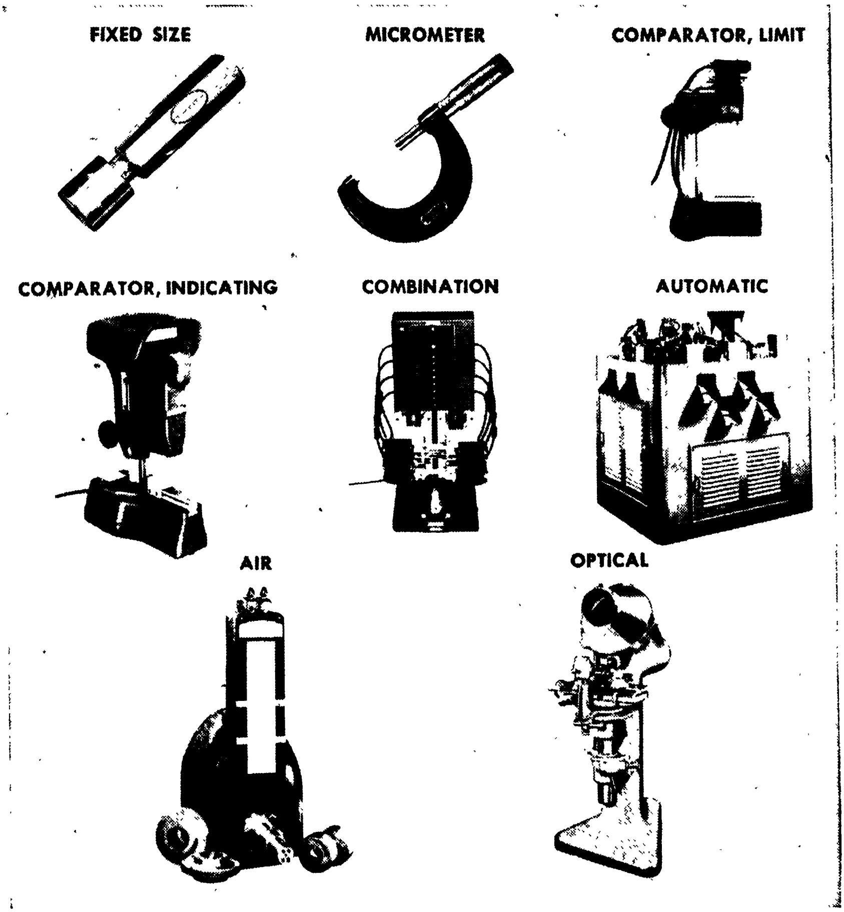



FIG. 33. Types of gages. (*Courtesy of Sheffield Corporation.*)

mon type of gage used in checking the dimension of a hole or bore, can usually be ground down to the next smaller size.

**Inspection Measuring Equipment.** Standards and the art of measurement have today come a long way from practices in the sixteenth century, when the lawful rod was stipulated to be the length of the left foot of 16 men as they lined up in back of each other coming

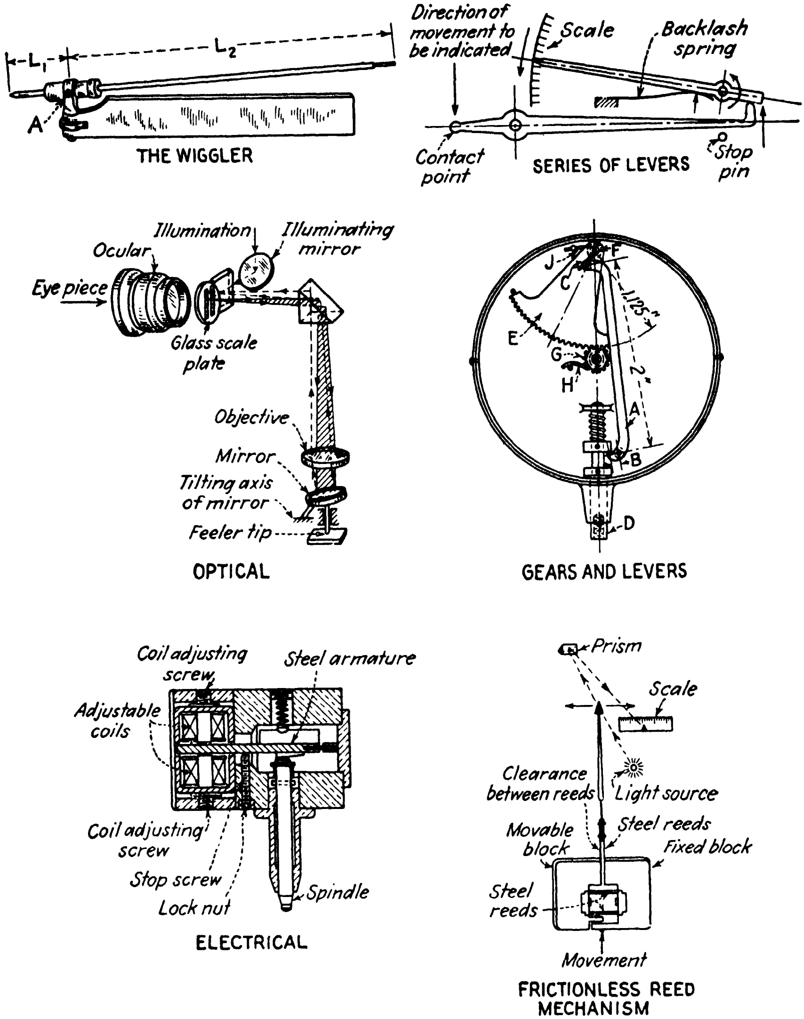



Fig. 34. Magnification devices. Device in lower right-hand corner is the Sheffield reed mechanism. A movable block is joined to a fixed block by horizontal alloy-steel reeds. Two vertical reeds, one from each block, are joined together and extended to a pointer. Vertical movement of the movable block in the gaging operation tends to cause the two vertical reeds to slip past each other. However, being joined at the end, the reeds instead of slipping cause the pointer extension to swing in an arc. This motion of the pointer is further magnified by a light beam operating through a series of lenses that project the motion on a scale in the form of a shadow. Such a "shadow gage" is the comparator-indicating gage shown in Fig. 33. (*Courtesy of Sheffield Corporation.*)

out of church on Sunday morning. Today our standards of measurement are accurately defined, and modern gages are now capable of measuring in millionths of an inch. A common standard of measurement used by industry in precision work is the Johansson Gage Block. These are rectangular pieces of hardened steel that are accurate down to a few millionths of an inch and are used in checking master gages.

Remarkable progress has been made during recent years in mechanical and automatic inspecting devices that eliminate the human element. The electric eye, for example, has been used in many production lines for the rapid location of defects. The photoelectric cell also has been used to grade such products as beans, to sort raisins at the rate of 1,000 per minute, to select electrical resistances, to control enamel thickness on wires, to check the level of the contents of a tank, to control the filling of bottles, and to locate fine cracks in metallic surfaces.

The uses of the industrial X ray are rapidly increasing for control and testing purposes. Already the X ray has been effectively used to detect flaws in castings and welded joints that would otherwise have remained undetected until the product suddenly failed in service. Scientists tell us that the X ray will be used in the near future in testing the constitution and practical behavior of metals, textiles, chemicals, glass, and numerous other substances.

In the electrical field, likewise, we have thermocouples for measuring high temperatures and the stroboscope for the examination of deflections of rapidly moving objects. Also aiding in the examination and testing of moving objects is the recently perfected science of high-speed photography, and the long-used slow-motion photography is still frequently called into service.

The manufacture of precision metal products requires devices for accurately measuring very minute dimensions or deviations from the standard dimension. One common device is the indicator gage. Such gages in common use permit the reading of measurements down to a fraction of one ten-thousandth of an inch.

Fairly accurate checking of forms or contours can be achieved with simple profile gages. These are merely templates cut to the shape desired, and on holding the object and the template up to the light it is easy to see wherein the shape of the object departs from the standard. But if a finer and more accurate checking device is required, a visual comparator of the type shown in Fig. 35 is often used. The ground threads at the base of an air-cooled airplane-engine cylinder barrel and other small and intricate shapes are checked in this manner.

The development of photoelasticity has given industry a new approach for the testing of stresses and strains in working parts. If a piece of colorless Bakelite or other transparent plastic is examined under polarized light, it appears to be grayish in color. But if the part is bent or strained, as it would be under operating conditions, and if it is viewed under polarized light, bright bands of color appear.

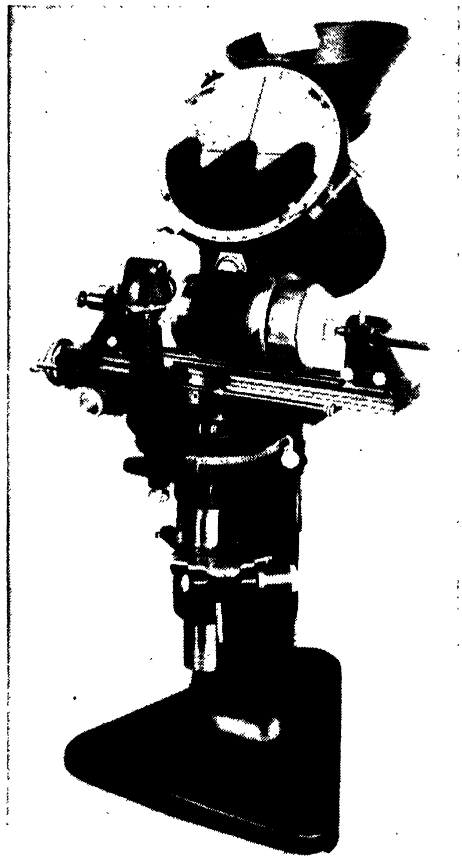


FIG. 35. Jones and Lamson comparator which magnifies on a screen the shape of the object tested.

The exact location and number of these color bands give an accurate picture of internal stresses. Automotive parts that are highly stressed, such as brake pedals and front spring control arms, are tested by this method by simply using plastic replicas. By this method engineers learn where to add or redistribute material to increase the strength of the part.

Color adapts itself to accurate measurement when it is broken up into its characteristics of hue, value, and intensity. There, again, the photoelectric cell is widely used in color analyzing and in ensuring the exact duplication of colors.

The measurement of surface finishes of metals has progressed in recent years from the indefinite and debatable "fingernail test" to a positive and conclusive instrument test. Whether the *surface analyzer* or its close competitor, the *profilometer*, is used for this purpose, it is now possible to measure surface-finish irregularities in terms of micro-inches (millionths of an inch).

In all fields of inspection there is a noticeable trend toward the introduction of automatic inspection equipment. Inspection devices measuring work size or other attributes of the part being processed are now often installed as a part of the production machine itself to control automatically the quality of the work produced. For example, a widely used internal cylindrical grinding machine employs a plug gage that with every grinding stroke of the machine endeavors to enter the internal hole or "bore" of the part being ground. When it is able to do so, the part is ground to size (frequently permitting tolerances as close as 0.0002 inch) and the machine is stopped automatically. More and more machines are being designed with automatic gaging equipment, testifying to the economies and increased control of quality that can be obtained by "machine inspection."

The foregoing are just a few of the many instruments and devices that have been developed to aid in inspection and quality control. Some are quicker than testing by human hand and eye; many are more accurate and reliable; but all are indicative of the rapid progress that has been and is being made today in inspection methods and equipment.

### CASE 16. QUALITY CONTROL

## Sample vs. 100 Per Cent Inspection

*Murray Metal Parts Company.*[1] One of the products of the Murray Metal Parts Company is a hardened steel pulley used in small marine applications. This pulley is turned on an automatic screw machine from bar steel. The shape of the pulley is such that it is difficult to set the machine to hold the close turning tolerances required of the part. Consequently, a 100 per cent inspection has been set up after the machining operation. Following this machining inspection the pulley is sent to the heat-treating room for hardening.

[1] Name fictitious.

Then successive grinding operations on the faces, outside diameter, and bore are performed, after which the part is cadmium-plated, then given a 100 per cent final inspection, packed, and shipped.

Over a period of the last two months, an analysis of the summarized reports of the machining inspection reveals that the rejections at this point have been averaging 5 per cent. The man in charge of methods is wondering if the 100 per cent inspection at this point is worth while or if, perhaps, it would be more economical for the company to limit the machining inspection to a sample (preferably 10 per cent) inspection for control purposes only and wait until the final inspection before giving the part a 100 per cent inspection, at which time he figures the 5 per cent poor material would be caught anyway and rejected.

To back up or refute this claim, he has gathered the cost figures listed here:

Cost per Pulley (figures include overhead)

| | |
|---|---|
| Material | $0 0010 |
| Turning (on automatic screw machine) | 0.0025 |
| Machine inspection | 0.0020 |
| Hardening | 0.0006 |
| Face grinding | 0.0025 |
| Outside-diameter grinding | 0.0021 |
| Bore grinding | 0.0023 |
| Cadmium plate | 0.0005 |
| Final inspection | 0.0030 |
| Packing | 0 0005 |
| Total | $0.0170 |

Average daily production—10,000 pulleys.

### Preparatory Question

Would you recommend that the machining inspection be limited to a 10 per cent sample inspection? Support your answer with figures.

## CASE 17. QUALITY CONTROL

### Inspection and Salvage of a High-quality Product

*Super Saws Company.*[1] Super Saws Company is a well-known New England concern that specializes in saws, metal cutters, knives, and files. Among the saws manufactured are two kinds of circular saw: the solid-tooth type, which is used mainly for woodworking, and the inserted-tooth circular saw, which is made with a relatively low carbon steel backing and special steel- or other alloy-teeth inserts.

[1] Name fictitious.

This second type is used primarily for the cutting of metal. A wide variety of styles and sizes of inserts is manufactured, and these are fitted to a standard line of backing sizes.

The concern maintains an inspection department consisting of 12 inspectors reporting to a chief inspector, who, in turn, reports to the factory superintendent. The inspectors have the authority to pass or reject any article but are expected to cooperate with the foremen insofar as locating and correcting the source of defective work is concerned.

Since saws are a high-quality precision product, they require very close inspection. Inspections are made after all important operations, most of the "in-process" inspections consisting of 100 per cent visual and dimensional inspections. In addition, at the completion of the manufacturing process the saws go through a final inspection before they are ready for shipment. At the final inspection the inspector checks the number, style, and spacing of teeth, "Rockwells" the saw (or teeth inserts on the inserted-tooth type of saw) for hardness, checks it for static balance, and finally gives it a visual examination for such things as steel irregularities, rust, etc.

Rather a high percentage of the rejections occur at this final inspection, and an analysis of the rejection slips shows that the principal causes of rejection at this point are hard and soft steel, teeth irregularities caused by poor grinding and sharpening, and rust.

### Preparatory Question

Comment on the inspection organization and procedure of the Super Saws Company, suggesting any improvements you feel would make for better inspection control. Is there any possibility of salvaging rejected material?

## CASE 18. USE OF QUALITY CONTROL CHARTS

*Hotpoint, Inc.*[1] Confronted during the Second World War with a rejection rate of 21 per cent on bullet cores turned on six-spindle automatic screw machines, one Chicago plant of Hotpoint, Inc., resorted to quality-control charts as a means of reducing its rejections.

Prior to that time inspectors had sampled the parts and simply recorded their findings, the resulting mass of figures being no help in checking up on the performance of machines while they were running. Hence considerable bad work was frequently turned out before discovery.

[1] Adapted from "Stopping Bad Work before It Happens," *Modern Industry*, Jan. 15, 1945, p. 33.

The heart of the chart control (see Fig. 36) is a system of colors which shows how each machine measures up on the various dimensions measured. Zero on the chart is the perfect dimension. But of course parts within plus or minus tolerances are acceptable. If these tolerances are, for instance, plus or minus 0.003 inch, the outside limits of the *white* band on the chart are plus or minus 0.002 (+2, −2 on "Over-all Length" chart).

Next to the white bands are *gray* bands, with limits of, say, 0.001 inch wider (+3, −3, on the "Over-all Length" chart). When measurements on parts are far enough from the perfect dimension so that the chart line moves into the gray area, the chart warns that the machine should be reset while dimensions are still within acceptable limits. (For an example, see (1) on "Over-all Length" chart for second shift.)

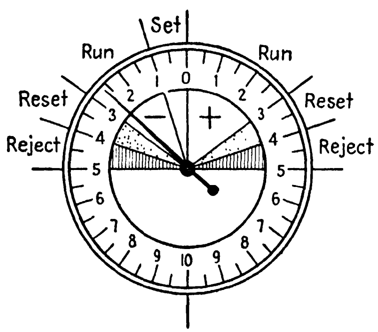



FIG. 37. (*Reproduced from Modern Industry, Jan. 15, 1945.*)

Beyond the gray bands are *red* bands. Parts whose dimensions fall in this area must be rejected. (For an example, see (2) on "Boat-tail Length" chart for second shift.)

To simplify the work of the inspectors, the dials on inspection gages are marked with colored bands (see Fig. 37) to correspond with those in the chart. If the indicator goes into the red area, for instance, the inspector knows at once that the machine must be shut down and the measurement plotted in the red on the chart. The area from 0 to −1 is for use in checking the machine setting. This color setting allows quick accurate reading of the gage dials with little or no training.

The inspection procedure instituted in conjunction with the charts is as follows: Every fifteen or twenty minutes a girl inspector goes to each of the five machines to which she is assigned. From the basket of parts made since the previous visit she picks 10 at random, gages them for dimensions, examines them by eye for such defects as toolmarks, etc. Largest and smallest dimensions found in samples are entered on the chart, while qualities judged by eye are marked good or bad.

Inspection completed, girl inserts card in holder on side of machine to show its performance. White card means everything is O.K. If one measurement slips into the gray band on the chart, a gray

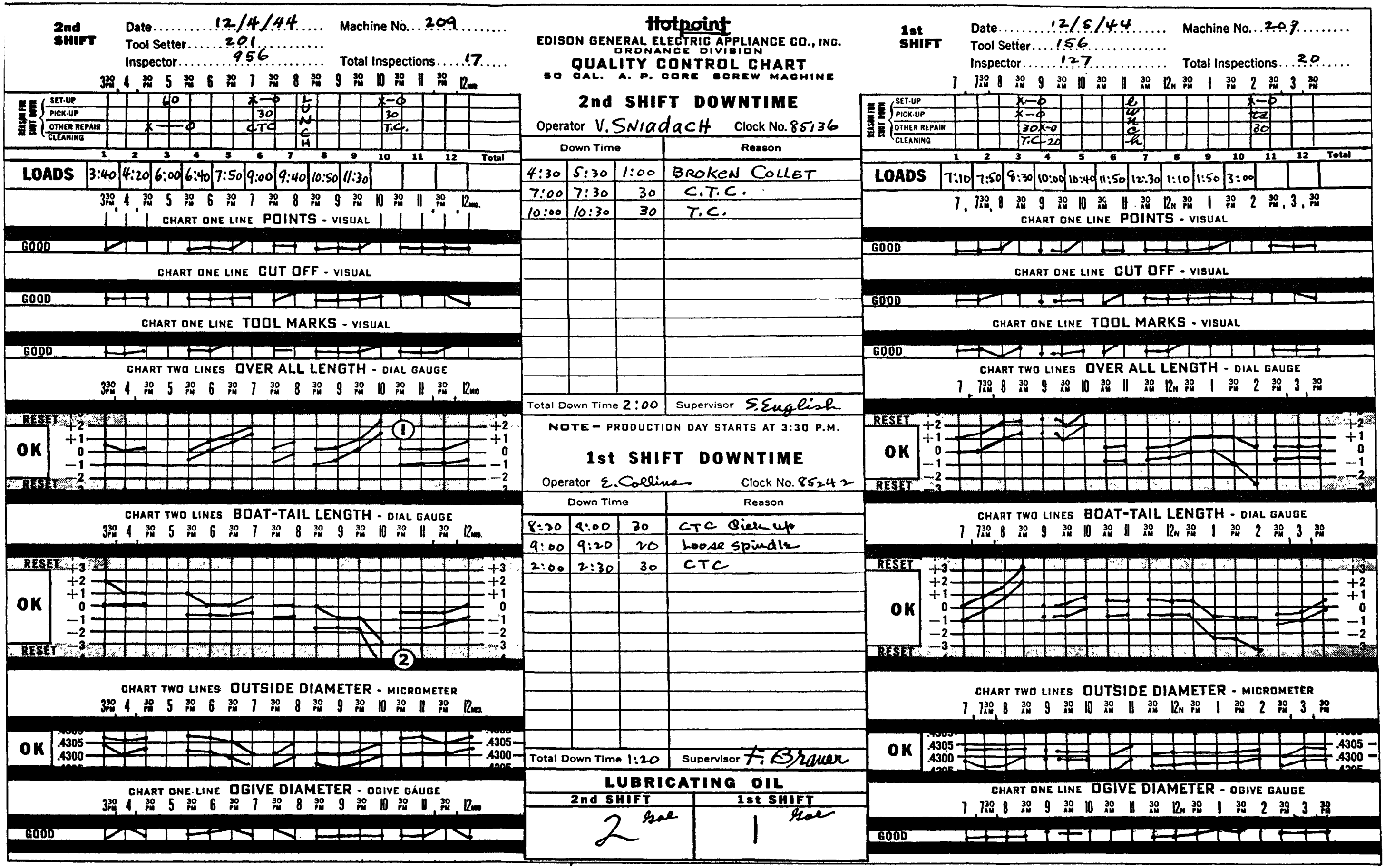



FIG. 36. (*Reproduced from Modern Industry, Jan. 15, 1945.*)

card goes up. The fact that quality is moving into the gray area indicates that trouble is on the way, and it then becomes the duty of the toolsetter to reset the machine before below-par parts begin to appear.

If any quality moves into red bands on the chart, the inspector slips a red card into the holder to mark the machine as unfit until reset. Machine operator is notified and must stop the machine. Machines with red cards have priority over gray cards for a toolsetter's time. Basket of parts from which red samples were taken is dumped into a yellow-topped barrel for individual inspection in another section of the plant. Baskets from machines showing white or gray cards are emptied into the "acceptable" barrel.

FIG. 38. Photo showing inspection station and quality performance card in holder on automatic-screw machine. *(Reproduced from Modern Industry, Jan. 15, 1945, and with special permission of Hotpoint, Inc.)*

Having completed repairs and adjustments, the toolsetter notes on the chart the reason for the shutdown and how long it lasted. Standard symbols are used to indicate more common reasons for a halt in machine operation. For example, the *TC* shown on the accompanying charts indicates tool change, *CTC*, complete tool change. After toolsetter has made final adjustments, the operator checks the dimensions of the first parts produced. If the pointer is within the area marked "set" on the dial face, the machine is ready to go.

## Preparatory Question

Comment on the merits of the quality-control system used at Hotpoint. What are the advantages and limitations of such a system for other kinds of products and for various types of manufacture?

# CHAPTER XIV

# RELATING COST TO PRODUCTION

**Accurate Cost Records a Necessity.** Manufacturing, as we know it today, is a complicated procedure, especially in industries devoted to production of a wide range of items of varying size, shape, and use. Given a single product of good design, filling an economic need that gets a ready market acceptance, and manufacturing this lone product in a plant equipped with proper machinery and an efficient personnel, we should have no difficulty in learning from the profit-and-loss statement whether or not the company is operating at a profit. There being but one product and no size variations of that product, the cost of manufacture can be easily obtained.

But let us consider a hypothetical case in which the margin of profit is not satisfactory, even in recognition of good sales acceptance and at a price that can be economically justified. A logical approach, then, to an analysis of the cost of the product would be first to satisfy ourselves that our basic product design is right, that the materials entering into its manufacture are economically as well as structurally correct, that our advertising and distribution costs are as low as can be expected, and last, but not least, that our manufacturing costs are of a proper value.

If we have been operating under a general accounting system that gives us blanket or over-all costs only, with no attempt made to break down the costs of the various manufacturing operations, we shall find ourselves in a very difficult position in our attempt to justify or reduce our manufacturing costs. For instance, to carry the illustration on, we shall have absolutely no detail cost data to which we can refer that will show us exactly what the cost of certain punch-press operations are, nor shall we know what our assembly costs are. Had we a detail cost system, we could easily make a comparative study on our punch-press operations and readily prove whether an investment in new and improved presses could be justified and, if so, what the savings would be. Carrying on still further, we would know just how much this would reduce our manufacturing cost, after the increased overhead or "burden" due to the purchase of

the new machinery had been accounted for and charged in the total manufacturing cost.

Along the same lines, a detail cost record of assembly operations might show us what further refinements could be practiced during the actual manufacturing processes that would result in faster or more accurate assembly. Our detail cost records might indicate a disproportionate amount of conveyors and power-operated assembly tools, etc.

In the preceding hypothetical case we have shown the need for detail manufacturing costs in a plant where but *one* article of one size and model is made. How important it is, then, to have detail manufacturing costs for a plant manufacturing machinery on a job-order basis, which, as described in Chap. IX on Dispatching, may have in process at one time over 1,000 separate manufacturing orders covering 700 types, sizes, styles, and classifications of machinery and equipment. This is, of course, the extreme of complication; nevertheless, there are many such plants in successful operation, and the key to their operation is an accurate, dependable cost system, on which they base future estimates and by which they are enabled to keep a close watch on current manufacturing operations. This last feature is often of great value, since through it a competent factory manager can readily spot excess costs in a particular department as they occur and can take proper steps to avert further excesses and consequent losses in money.

Industry throughout the nation profits by accurate cost data. Any purchasing agent can tell of instances in which a compilation of figures received as selling prices for manufactured articles will reveal a very close-running level of prices, and then often certain vendor's prices will depart from this common level and rise or fall above or below it by fantastic differences. Generally speaking, these are the vendors who do not know their costs, or, if they have a semblance of a cost system, they have misapplied the information it gave them. This makes it difficult for the vendor who does know his costs, especially if the articles in question are to be built to standard specifications. Sometimes he loses or may fail to receive consideration of his bid, or if he is the successful bidder, he may only find himself one step nearer bankruptcy.

There are two schools of thought on the ethics of this problem. The first says that a school should be maintained within each industry to teach standard cost-finding practices for that particular industry. The second says that time takes care of the companies with inaccurate

cost systems, and eventually they go down in financial ruin and thus remove themselves with their disturbing competition.

**The Elements of Cost.** The three basic elements entering into all cost accounts are material, labor, and overhead expense. There are, however, further detail classifications of each of these fundamental elements that we shall consider.

Taking material first, we find that all material that is used directly in the manufacture of the product is classified as *direct* material; other material that may be equally essential to the operation of the factory but that does not enter directly into the manufacture of the product is classified as *indirect material* or *expense material.* Thus, in the manufacture of aircraft engines, aluminum forgings that are a part of the engine are classified as direct material, whereas the fuel oil used to heat the plant is classified as indirect material or as expense material.

Considering labor, we find that all labor entering directly into the operations necessary for the production of the product is termed *direct labor.* However, a good percentage of the labor necessary in a plant is not directly engaged on actual production operations and is therefore classified as *indirect labor.* Examples of these classifications might be the machine-tool operators working on the aluminum forgings in the aircraft-engine plant, who would be classified as direct labor, whereas the attendants operating the oil-fuel heating boilers would be classified as indirect labor.

Overhead expense is an item that is neither direct material nor direct labor. Examples would be taxes, insurance, depreciation of plant and equipment. It is obvious that the direct material and direct labor involved in producing a product can be easily allocated to the cost of that product, but the allocation, for instance, of a portion of the taxes on the plant to the cost of that product is much more difficult. However, an accounting must be made of these expense items, since they often run into tremendous sums. Therefore, they are grouped together and classified as overhead expense.

**Cost-element Classifications.** In addition to the general-office, clerical, and accounting expense, the sales expense, which will include sales-department salaries, traveling expenses, etc., is included in the cost classification of overhead expense. It cannot be definitely charged to any particular order or job and is therefore spread over all orders. A further breakdown of this is often made by charging the expenses incurred in the general administration of the company to administrative expense, the general expense incurred in the operation of the factory to

factory expense, and those expenses incurred in the selling of the product to sales expense. Often administrative and sales expenses are grouped together and called *general expense* or, by some concerns, *administrative expense.* Where selling costs are high, as in direct selling by door-to-door salesmen, the separate classification of sales expense should always be used.

If we take as an example a given value of material and add to it the labor cost of converting the material into a manufactured product, we incur a definite expense for material and labor, which is often known as the *prime cost.* Now there is a certain amount of factory expense incurred, while thus converting the material by labor, that must also be added to this prime cost, the sum of which is called the *factory cost.*

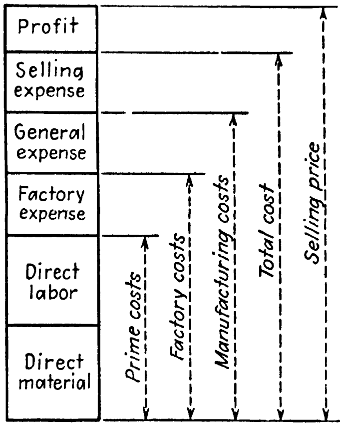


FIG. 39. Classification of costs.

Up to this point we have produced the product, but in so doing we have made use of the administrative and management facilities of the organization, for which a prorated charge must be made in the form of general or administrative expense. This, added to the factory cost, results in a new total, termed the *manufacturing cost.*

However, our product must also bear its share of the cost of advertising, maintaining a sales department, shipping, etc., which, when classified separately, is termed *selling expense,* but when added to the manufacturing cost may be termed a *total cost.* Added to the total cost must be the profit we expect to make on the order. This final addition results in the determination of the selling price of the product.

These classifications of costs may be observed in Fig. 39, which is a simple diagram showing graphically the elements of cost and how their summarization develops on production cost and a selling price. No attempt has been made in this figure to show the value of the element of cost proportionately, since this will vary with different articles and different organizations.

**Distribution of Expense.** It is not a very difficult matter to allocate direct material and direct labor to the manufacturing order, stock order, or job order, as the case may be, provided that a proper timekeeping and material-control system is installed and used. This, of

course, requires that all withdrawals of direct material be charged to the proper order number and that all direct labor be charged to the order number on which the workman was employed. Consider, for example, a machine operator performing a milling operation on an aluminum piston for an aircraft engine. The casting was purchased and allocated to an order number, and the operator's time was charged to the same order number. But let us suppose that the electric motor powering the milling machine fails and has to be repaired by the electrical-maintenance crew. Obviously the cost of this repair cannot, under ordinary operating circumstances, be charged to the particular job number on which the operator was working when the motor failed. Nor could the repair of a leaky steam valve be charged to any one production order, because there might be any number of current production orders in process in the department in which the leak occurred. By the same logic, other expense items such as wages paid to crane operators, watchmen, supervisors, etc., who have general duties, cannot be charged to any particular order number. The same restrictions would apply to insurance and taxes, power and light charges, and many other general factory expense items.

Means, therefore, must be developed that will ensure a fair and just distribution of expense to the departments involved and to the plant as a whole. The problem in cost accounting is the development of a system for the allocation of the various expense accounts to shop orders, with due regard for the proportionate use by various departments of the plant of the facilities that incur the expense. The distribution of expense on an absolutely mathematically correct basis is well-nigh impossible, since so many factors are nebulous and open to human judgment and consequent error. The larger and more complex the industry and the plant, the greater will be the difficulty for exactness of distribution. If, for instance, a plant consisted of one operation, conducted in one small room, we should come much closer to an equitable distribution of expense than we could in a diversified manufacturing plant, consisting of, let us assume, over 100 buildings, with 200 or 300 processes being performed concurrently on machinery and equipment of widely varying characteristics, requiring a wide variation of plant service functions, such as watchmen, maintenance men, crane operators, janitors, sweepers, etc.

**Methods of Expense Distribution.** *The Material Basis.* This is an expense-distribution basis that can be used with any degree of accuracy in a continuous-process plant only, making one uniform product such as cement, crushed stone, or sulphuric acid. It is

obvious that if only one product of one size is made, the total expense for a given period may be found by dividing this sum by the output in tons, pounds, gallons, barrels, or whatever the unit of measurement may be. The quotient is the expense burden per ton, pound, gallon, barrel, etc. But let another kind, size, weight, etc., of product be run through, and the effect of the variation would be so great as to give false figures. Thus the net result would be worthless from an accounting standpoint. For that reason the material basis is used only in continuous-process industries.

*The Direct-labor Basis.* The simplest method of distribution of expense in an intermittent-process plant is that which uses the cost of direct labor as a basis. This simple but inaccurate method is based on the assumption that the indirect expense that should be charged to a shop order or job is some proportion or percentage of the direct labor expended. Thus, if experience shows that when the direct-labor pay roll for a quarter has been $30,000 the indirect expense has been $10,000, then the percentage or ratio of expense to labor has been 33⅓ per cent, or one third. Then, if we were to allocate indirect expense to a stock order made during that period, which carried a $9,000 direct-labor charge, we should add 33⅓ per cent of that amount, or $3,000, as expense, making a total factory cost of $12,000.

The direct-labor basis neglects one of the foremost principles of modern manufacturing—the part played by time in cost. Suppose we have a man who is slow by nature, who is receiving $0.60 per hour, and who takes five hours to do a certain operation, making a total of $3 direct-labor charge. Then let us assume another man on another job who by nature is faster and receives $0.75 per hour. He takes four hours to turn out a comparable job, and he thus runs up a $3 direct-labor charge and is ready for another job at the end of four hours, whereas his slower shopmate will not finish his job for another hour. In the meantime, charges for heat, light, power, insurance, and taxes are going on hour after hour, and it is easy to see that the faster man is getting a greater turnover on the overhead or burden expense. Greater utilization of plant, equipment, and personnel is the answer to the cry for lower manufacturing costs. Moreover, this method is accurate only when the work is always of the same size and character. Just as soon as we encounter a variation of sizes, designs, and raw materials, the error becomes great. Further, it takes no account of the equipment investment. The labor of a man using nothing more than a small air-driven grinder costing $75 is charged with the same expense burden on his $10 worth of direct labor as that charged to the operator of a

gear-generating machine, costing upward of $150,000, that must be served by a $15,000 traveling crane.

*The Man-hour Basis.* This method assumes that the expense chargeable to a shop order or job is in constant proportion to the man-hours charged to it. By this assumption we have one improvement over the direct-labor basis, inasmuch as on the man-hour basis we shall give some recognition to the fact that in few plants are all men paid the same rate. This method, although taking cognizance of the time element or turnover in modern manufacturing, does not recognize the difference in value and character of shop equipment and makes no provision for an expense distribution on that basis.

*The Machine-rate Basis.* From the foregoing brief descriptions of the material basis, direct-labor basis, and the man-hour basis, it has become evident that each of these methods is inaccurate because it neglects to differentiate between the cost of using small, relatively low-cost tools and equipment and large, extremely expensive tools and equipment.

Management, engineers, and cost accountants recognized this fault a long time ago and developed the machine-rate basis, which takes these differences into account. The theory and logic on which this basis of expense distribution rests are more accurate and scientific than any of the bases heretofore described.

Briefly, the principle is this: the time taken to perform an operation and the rates of the operators being equal, it costs a considerably greater amount to perform an operation with a $150,000 gear-generating machine served by a $15,000 traveling crane than it does to perform an operation with a $75 air-driven hand grinder. This is obviously true, because the gear generator represents a larger capital investment, any maintenance or repairs to it are costly, it takes many times more power to run it, and it takes up much more floor space, thus making it liable for higher charges for heat, light, insurance, etc.

In setting up a machine-rate basis for expense distribution, a thorough analysis is made of depreciation, floor space, power requirements, lighting requirements, etc., for each machine or groups of similar machines. The expenses are thereby estimated as closely as possible. The total expense charged to any machine or group of machines is then divided by the estimated number of hours the machines will operate during a given period, and the rate is thus evolved.

In making up the estimated number of hours that the machines will operate, recourse must be had to past records. These records must be altered and revised in view of business conditions that may reasonably

be expected to prevail during the period to be covered. This estimate is usually termed the *budget* for that particular group or department, and the actual operation of that department or group at the number of hours previously estimated is sometimes termed the *break-even point* or *picking up the budget.*

With the use of the hourly machine rate it becomes an easy matter to distribute the expense properly, since the expense is a part of the machine rate so evolved. For instance, the machine rate on the air-driven hand grinder might be $1.25 per hour, whereas the rate on the gear generator might be as high as $7.50 per hour of operation.

From the above it will be seen that if the allocations of expense have been correct and if all machines have been operated the exact number of hours estimated when the operating budget was made up, all the expense will be properly distributed. But if for any reason the machines do not operate the number of hours for which they are budgeted, the proper distribution of expense then fails to be shown. For example, let us assume that because of a slump in business no work is available for the large gear-generating machine previously mentioned. For every eight-hour day that this machine stands idle, a loss is incurred of 8 × $7.50, or $60.[1] This deviation from the operating budget is usually handled by transferring the amount of this "unapplied burden" to the profit-and-loss statement. In times of business depression this may become a considerable factor.

Always bear in mind that a plant cannot be locked up and forgotten. Taxes, insurance, watchmen's salaries, etc., go on as usual In fact, they may be higher. Idle machinery may be likened to a draft horse with no work to do who idly "eats his head off."

However, in times of great business activity the operating budget may be exceeded by a great margin, in some instances in excess of 300 per cent. This would mean that a plant with an operating budget of 10,000 hours as sufficient to cover all expense would be working 30,000 hours on the 300 per cent budget with the same equipment. This could be done by working up from one shift to three shifts. It is obvious what an opportunity for business profit exists under these conditions.[2]

**Timekeeping.** Time records taken from time tickets or job tickets turned in by operators are posted to cost records, which in some

[1] The actual loss might be decreased to some extent by savings in light and power while machines were idle, especially if the company purchases light and power from the outside on a meter basis.

[2] The use of a variable budget as a means for calculating costs at all levels of production was described in Chap. VI.

plants are combined with production-control records. The time values may be converted into dollar values at the time of posting or may be converted by the cost department later.

There cannot be too much emphasis on the necessity for accurate timekeeping records, because accurate timekeeping is the basis for almost all cost and production data. In far too many plants the post of timekeeper is considered the lowest rung in the ladder and is the starting point for inexperienced boys and girls, who are paid accordingly. And yet they are dealing with the element of direct-labor time, which has such an important bearing on the costs of the company. Moreover, because of their inexperience in industry, these boys and girls are usually ignorant of the shop processes that are the basis of the time values with which they work and are in no position to challenge or question the correctness of the time values. A study of the possibilities for error, waste, and intentional "adjustment" of time values that are present in the ordinary day's work of a shop timekeeper would amaze management if the work of a timekeeper actually and thoroughly were gone into. Cost records can be no better or more accurate than the data on which they are based, and these data usually emanate from a timekeeper.

**Production Reports—The Basis for Cost Data.** There is a very close connection between the work of the production-control department and that of the cost department. Unfortunately, in many plants there is not a full realization of the fact that the gathering of cost data is not just a bookkeeping function but a vital element in the control of manufacturing operations. Cost accounting is the instrument by means of which management is supplied with these important data.

Since cost data are derived from actual production operations, it is easy to see the responsible position in which the production-control department is naturally placed.

One of the most difficult educational jobs in most plants is to indoctrinate each member of the production-control department with the necessity for using the utmost care in preparing reports concerning production times, schedules, etc. Great progress has been made in some companies, with the result that from the stock-chaser on up through the rank and file, each man knows not only *why* he performs a certain operation but also what important report may depend on the data he furnishes.

**Cost Analysis.** Cost reports, as issued by the cost department, form the incentive for a minute analysis of the costs as shown by the cost reports. Such reports may indicate a disproportionate relation

between direct and indirect labor or may show a bad ratio between machining time and assembly time. Or they may show such a narrow margin of profit that it is evident that a thorough study must be made starting with design and carrying through to sales policies.

Cost reports must be issued as promptly as possible after the completion of a shop order; otherwise the information they contain will be stale before it can be used as a basis for corrective action. The reports are, in truth, merely a tabulation of figures and as such have little constructive value.

Placed before an experienced executive, however, cost reports enable him to visualize two things: (1) they give him a clear picture of what *has* occurred, and (2) they enable him to visualize what can be *made to occur* when certain corrective influences have been formulated and put to work.

### CASE 19. SEGREGATION OF DIRECT AND INDIRECT LABOR COSTS

*Reliance Machine Works.*[1] Direct labor is an important element of cost in all industries where either skilled mechanics or highly trained operators are employed in the actual manufacturing operations and processing of the product. The segregation of direct-labor costs from the indirect-labor costs is of utmost importance, as the economic life of a company may often be measured by the direct-labor costs that must be applied to its products sold in a competitive market. However, the Reliance Machine Works, founded many years ago, had not kept up with competitors in its field in the utilization of modern systems of cost allocation in its simple cost accounting system.

This was a *job shop,* as most of their work was short runs of small quantities, made on a customer's special order. The workmen entered on daily time cards the shop-order number of the jobs they had worked on, using their own estimates of the time they had spent on each. A new cost accountant was added to the staff, and in the course of making a cost analysis of repeat orders for duplicate items, he noted wide variations in operation costs, which were particularly revealing inasmuch as the orders had been processed during a period of relatively static labor rates. His investigations took him into the shops, where he found that each operator made out his own time card for each day, using his personal estimate of the time spent on each job if he had worked on more than one. The cost accountant also found that, in several instances, indirect labor that should have been apportioned to several jobs had been charged to one job.

[1] Name fictitious.

The competition was getting keen in one of Reliance's major lines and the management knew that survival in this particular field would be possible only if they knew exactly what their costs were and could make their selling prices accord with these costs. There was definitely something very wrong with their existing system of allocating both direct- and indirect-labor costs.

### Preparatory Question

Assume that you are the new cost accountant and know that your present situation and future progress both depend on your ability to change Reliance Machine Company's cost system to one that will reflect actual time consumed in a more realistic manner. You have authority to make recommendations and to install changes that should bring about the desired result. Describe (1) the changes that you would recommend; (2) the method by which you would install and operate them with the least friction with operating personnel; and (3) the forms of time cards you would use.

# CHAPTER XV

# COORDINATION

**Necessity for Coordination.** No matter whether the plant be a small one employing 100 people or a colossus of our modern industrial age, the necessity for coordination of effort always exists. Obviously, the larger the plant the greater is the necessity for tying together all the departmental functions as a means of obtaining a smooth-working production organization, operating with a minimum of lost motion, friction, and delay.

If we were to draw a simile from the familiar things of life, we might liken the "one-man plant," managed by the owner, to a "one-man band." Musically, the "one-man band" produces harmonies to the satisfaction of many, including himself. He is continually changing from one instrument to another and presents a picture of feverish activity. Similarly, the management of the "one-man plant" must of necessity assume from time to time the role of superintendent, planning engineer, purchasing agent, designing engineer, etc.

Then let us consider a full symphony orchestra, conducted by the leader—the coordinator. Here we see and hear a wonderful example of teamwork and coordination. The same relationships exist in a large production organization; all must be coordinated like the orchestra, or discords will result.

Almost every manufacturing organization contains some individualists who would rather "play the score" as they see it and as they want it to be played than become a cooperating member of a coordinated group. But usually, if the necessity for team play can be tactfully presented to them, they will learn to play their part for the general benefit of all.

About the first place we shall find cooperation and coordination well practiced is in the sales department in its dealings with the customer. Obviously the function of the sales department is to sell goods or equipment or whatever the product may be. Aside from matters of price and quality, the customer is usually interested in delivery, and here is the first hurdle the sales department must clear in its dual relationship as advocate of the customer and also a department of a production organization.

It is natural for the sales department to see the customer's viewpoint--that is one of its duties. But often the customer's viewpoint is seen in such fine focus that the over-all background, which we shall say represents the production organization, is blurred and out of focus. It must be stated in candor that too few sales organizations have a real, practical operating knowledge of the problems surrounding the production of the goods they sell. But if, by a slow process of education, this knowledge can be imparted to them, together with an over-all view of where they fit into the organization picture and why coordination of *all* departments is a necessity, great progress will be made.

After the customer's real needs, as distinguished from his wants, are determined by the sales department, the first attempt at coordinated operation should lead this department to consult with the manufacturing department and arrange an honest and workable shipping schedule that can be lived up to in the light of conditions as they may exist at that time. One of the greatest industrial difficulties in the past, and perhaps the one point that has led to the adoption of more production-control systems than any other single issue, has been the proclivity of the sales department to quote whatever delivery date a customer may want, in an effort to obtain the order, and then to leave the problem in the lap of the manufacturing department. Happily, this unfortunate and demoralizing situation is on the wane, and enlightened organizations have seen the problem and have installed means to solve it to the satisfaction of all.

Again, the sales department must coordinate its efforts with those of the engineering department when there are designs, changes in designs, or specifications involved. Substitution of materials may be necessary, especially in times of great industrial activity, when certain materials become difficult and, at times, impossible to obtain. The sales department must be wary of leading the customer to think in terms of something its factory cannot produce. In most well-ordered organizations today, very stringent procedures are set up and maintained to the end that orders are obtained for only those goods that can actually be produced by the plant at a profit.

Once the order has been accepted and entered, the production-control department should exercise its control functions and coordinate the work of the engineering department with the requirements of the manufacturing department. Parallel with this requirement is the coordination of the purchasing of material and semifinished or finished parts with the requirements of the manufacturing department.

In the chapter on Scheduling, means are disclosed in detail for scheduling an order. Every effort must be made to maintain this schedule in the light of conditions as they exist from day to day. As has also been pointed out in other portions of this book, the coordination of purchasing with manufacturing is most important, and failure to make such coordination often spells ruin to an otherwise carefully planned manufacturing schedule.

**Coordination of Plants.** Since multiplant operation is now common, several types of problems have arisen and have been solved by companies with more than one plant.

If such holdings are separate units, each devoted to the manufacture of the same type of products, the question of coordination is relatively simple. Usually a separate control organization in each plant, reporting to the production-control manager at the main office for over-all results, will suffice.

However, when one or more plants contribute in some way to the production of other plants, the size and scope of the problem of control is vastly increased. Experience has proved that the handling of these plants from the point of view of coordinating production cannot be done in the same way that an entirely disassociated plant of an outside vendor would be handled. An understanding of mutual problems must be built up among the production-control personnel. This is often best accomplished by the interchange of production-program information for the current period, supplemented by telegraph, telephone, and teletype connections between plants and, most important of all, visits at regular intervals between plants.

Each company will have its own peculiar problems in this matter of multiplant operation, but for purposes of illustration a typical system of control of multiplant operation will be described. The example chosen is from the machinery-building industry, with all operations on a job-order basis and with weight of product running from a few ounces up to 200 tons.

The company has three plants, widely separated, and whereas each of the three has its own particular line of production, each one contributes to the production of the other two as well. The main offices of the company are located at one of the plants, which happens to be the largest of the three.

Monthly production schedules, covering the operations of the company as a unit, are made up and distributed to each plant. In addition, schedules are made up showing what each plant must produce for each of the other two plants of the company for that month.

For instance, one plant produces all welded parts that are used for the other two plants. Another plant produces all gears of a certain type that are required by the other two plants, as well as those it requires itself. Two of the plants produce iron and steel castings for all three. To complicate matters further, two of the plants have engineering departments that design for all three plants.

It is obvious to anyone experienced in production control that this multiplant organization requires very close control and constant vigilance; otherwise schedules will get out of control, and confusion will result. Over a period of years, the following procedure has been developed. On receipt of the monthly production schedules referred to, a list of exceptions and a brief explanation of present status and anticipated delays are made up by all three of the plants and sent in to the production manager. It is his duty to evaluate the urgency of each order or contract and make such adjustment of schedules as his judgment dictates.

Following this, he visits each of the three plants, discussing with the plant production manager the status of each order and the adjustments of schedules that he may have made. They may agree to the necessity for certain readjustments of schedules as the conditions warrant. On his return he consults with the various sales divisions and advises them of the new schedules for the next month, together with reasons therefor, so that they may properly advise their customers of any changes. The master schedule for the over-all operation is thus obtained and is maintained for the period of that current month unless unforseen circumstances make necessary a further readjustment, which is often the case.

In addition to this interplant visit, constant use is made of telephone, telegraph, and teletype connections between plants. Interplant visits are also made at regular intervals by executives of the engineering and manufacturing departments.

To handle the volume of interplant correspondence and wire communications, one man has been selected in each plant who devotes his time exclusively to these interplant matters. Assuming that he is in plant *C*, he acts as a clearinghouse for all manufacturing-department communications between his plant and plant *A* and plant *B*. The same is true of his counterparts in those plants. Working under the supervision of the production manager, he is thus able to furnish instant information as to the relations between his home plant and either or both of the other two, and can also orient this information with the over-all operations of the company.

The coordinated control thus described extends to the engineering and purchasing departments and has been proved by time and experience to be the right method for this particular company. Doubtless other companies manufacturing a different product would not find this arrangement workable in all details, even with the same number of plants. Like all systems of industrial control, whether they be cost control or production control, they must be altered and adjusted to fit the needs of the particular company.

**Coordination of Communications.** Control is dependent upon a continuous, accurate, and speedy flow of information indicative of specifications, schedule of production, schedule of materials, procurement, and the various other elements described in preceding chapters of this book. The greater portion of the cost of a product usually is in the burden or overhead charges, and often the greatest portion of these burden charges is contained in the wages paid to service personnel who accumulate, interpret, and transmit control information. Yet comparatively little has been done toward methods improvement in communication in most plants.

Beginning in the early twenties, forward-looking companies and their executives began to realize that the development of better methods of manufacturing was truly the master key to a universally higher standard of living. They realized that the time was coming when labor would have a more powerful voice in management affairs. Consequently the profits of industry could no longer be increased through rate cutting and low wages; the day of slave-driver methods for getting increased production was fast waning. As a result, they began a systematic program for the development of the techniques we now know as methods engineering. Today production-methods improvement is recognized by most companies as a major continuing staff function.

Unfortunately this movement toward methods improvement has to date been limited very largely to direct-labor operations. Methods engineers in all but a few of the more progressive plants lightly by-pass such operations as filling out forms, calling the toolroom, or other details that they seem to feel are unimportant. It is only in recent years that producers of office forms have supplied specialists to analyze the customer's job requirements, using standard work-simplification procedures. These specialists now seek to analyze the job to be done and then construct the communication instrument (form) that will serve most efficiently in terms of speed, cost, accuracy, and general effectiveness.

During the Second World War telephone company representatives were called in by industrial customers to advise on better utilization of existing telephone equipment, since additional equipment was not available. This cooperative effort produced some significant findings. In one manufacturing company it was found that seven different people had called one vendor about the same order in one day. Further investigation indicated that this lack of organization and coordination of communications was not unusual. It was found in other plants that production was held up while needed raw material waited unannounced in the receiving department. A telephone call from the receiving department as a part of standard procedure upon receipt of goods would have supplied information essential to proper coordination between material procurement and production.

**Organization for Communications.** The importance of designation of authority and responsibility has been stressed throughout preceding chapters. It is equally important in the coordination of communications. In the case of the seven people who called the one vendor about the same order, described above, there should have been clear designation of responsibility to one individual. Such designation might have been by type or kind of raw material or part involved, by product line, by vendor, or any of a number of other classifications most suitable to the company involved. "Everybody's business is nobody's business." Unless there is proper organization, control information is procured only in case of failure or emergency and by the person who happens to encounter the emergency first. The result is costly delay affecting the entire company. Responsibility for the routine accumulation of information essential to control must be designated.

**Standardization of Communication Procedures.** How shall the information be accumulated? How and when shall it be transmitted, and to whom? These are questions of procedure. Edwin B. Gage of the Western Electric Company effectively describes this problem, using the sorting of mail for illustrative purposes.[1] He suggests that generally there are three stages of development of a work load. At the small business level—which includes the introduction of a new operation—the load may be comparatively light, making a manual method most economical. As the work load grows, this method tends to be continued for a long period of time and after it has ceased to be true economy. Here the introduction of a semiautomatic machine

[1] GAGE, EDWIN B., "Standardization—Element of Efficiency," *Systems for Modern Management* published by the Systems Division of Remington Rand, Inc., October, 1946, p. 11.

method after a period of delay produces sav'ngs that should have commenced much sooner. With further growth or expansion the same kind of delay occurs before the third stage, with the complete mechanization of the detail work, is accepted.

In a small operation, it may be perfectly practical for a secretary to sort mail on her desk. As the volume grows, a mailroom separates and routes the mail, using some sort of pigeon-hole arrangement to hold material during sorting for distribution. With still further growth, this becomes impractical, and so prop-

FIG. 40. Modern sorting equipment for the mail room. (*Reproduced through the courtesy of Remington Rand, Inc.*)

erly tabbed manual sorting racks are adopted, perhaps with a preliminary sort or two to segregate action papers from purely informative material and material for various floors or buildings before the fine sort by addresses is made.[1] The proper sorting device multiplies the amount of work that can be turned out by a clerk in an hour or a day, thereby saving the cost of additional salaries, desks, and floor rentals, and, more important, getting action papers to the addresses much more promptly than they could be dispatched merely by multiplying facilities and personnel.[2]

Figure 41 shows the charting of the old and the improved method in obtaining credit information. This is another illustration of the

[1] See Fig. 40 for an illustration of modern sorting equipment.

[2] GAGE, EDWIN B., *op. cit.*

## OBTAINING CREDIT INFORMATION

### OLD METHOD

| Distance in feet | Time in minutes | Symbol | Operation |
|---|---|---|---|
| | | △ | |
| | 3.00 | O-1 | Clerk fills out application in long hand at bank |
| 10' | .06 | T-1 | Walks to clerk's desk and deposits in bank |
| | 60.00 | D-1 | Awaits pickup |
| | .25 | O-2 | Picked up by clerk and sorted |
| | .50 | INS 1 | Reads over application carefully |
| 10' | .06 | T-2 | Walks to phone |
| | 8.50 | O-3 | Phones credit bureau and gives name, address, tel. no., place of employment, position, length of service, four references, real estate owned and its value-recorded in long hand by clerk at Credit Bureau original filed by bank clerk |
| 20' | .12 | T-3 | Credit Bureau clerk walks to file |
| | .02 | O-4 | Open file |
| | .50 | O-5 | Find file copy and remove-reviews report if over 30 days |
| 20' | .12 | T-4 | Walk to desk and sit down |
| | 4.50 | O-6 | Copy necessary information from file |
| | 6.00 | O-7 | Type report on special form in duplicate |
| | .25 | O-8 | Place original in envelope and mail |
| | 360.00 | D-2 | Await messenger |
| | 60.00 | T-5 | Carried to bank by messenger |
| | .01 | O-9 | Deposited in "MAIL IN" basket |
| | .50 | O-10 | Pickup report and open |
| | 1.00 | INS 2 | Read carefully |
| 10' | .06 | T-6 | Walk to file |
| | .52 | O-11 | Remove original from file |
| 10' | .06 | T-7 | Return to desk |
| | 2.00 | INS 3 | Check against original |

FIG. 41. *(Reproduced through the courtesy of*

## NEW METHOD

| Distance in feet | Time in minutes | | |
|---|---|---|---|
| | | △ | |
| | 3.00 | O-1 | Clerk fills out application in long hand at bank |
| 10' | .06 | T-1 | Walks to clerk's desk and deposits in basket |
| | 60.00 | D-1 | Awaits pickup |
| | .25 | O-2 | Picked up by clerk and sorted |
| | .50 | INS. | Read over application carefully |
| 10' | .06 | T-2 | Walks to teletypewriter |
| | 6.00 | O-3 | Types to Credit Bureaus-name, address, tel. no. place of employment, position, length of service, four references, real estate owned and its value-keep typed copy on desk |
| | .20 | O-4 | Remove two (2) copies from teletypewriter at Credit Bureau |
| 20' | .12 | T-3 | Walk to file |
| | .02 | O-5 | Open file |
| | .50 | O-6 | Find file copy and remove reviews report if over 30 days |
| 20' | .12 | T-4 | Walks to teletypewriter and sits down |
| | 6.00 | O-7 | Types information on teletypewriter from file |
| | .20 | O-8 | Remove from teletypewriter at bank |
| | 2.00 | INS. 2 | Read carefully and check against original taken from basket file on desk |

### COMPARISON OF METHODS
#### OBTAINING CREDIT INFORMATION

| | Method Old | New | Difference |
|---|---|---|---|
| Time required to process new application | 8.+ hrs. | 1.+ hrs. | = 7.+ hrs. |
| Direct labor expended | .622 " | .316 " | = .306 " |

Direct labor savings/application @ \$.70/hr. = .306 × \$.70 = \$.21

| | | | |
|---|---|---|---|
| Direct applications processed monthly = 600 | | | |
| Savings/application | \$.21 | | |
| Monthly savings | | \$126.00 | |
| Postage and material | | 10.50 | |
| Other* | | 8.00 | |
| | | | \$144.50 |
| Cost of teletypewriter service | | | 90.00 |
| Net monthly savings | | | 54.50 |

* Old-type statement monthly 12 hrs. × \$.70 = 8.40
New-count teletype slips .5 " × .70 = .40 \$8.00

J. L. Schwab, *Methods Engineering Council*.)

possibilities for increasing the effectiveness of the communication and at the same time reducing the cost through systematic analysis and standardization of procedure. Note that through the utilization of teletypewriter service there was a monthly saving of $54.50 per month. But perhaps even more important is the fact that the time required to process new credit applications was reduced from eight hours to one hour. It should be emphasized, however, that although this saving in cost and time was possible in this particular company, circumstances in another company might make application of the teletypewriter service wholly inappropriate. The case is used to illustrate possibilities for communications improvement and to emphasize the importance of systematic analysis of procedures.

Appendix A, Written Standard Practice, reproduces excerpts from the written standard practice manual of the United States Rubber Company for its footwear plant at Naugatuck, Conn. This manual represents an attempt to analyze routine written communications, construct the best procedures for performing the jobs in question, and then require these procedures of all who are responsible for the jobs. Note that dates are set in advance for the review of procedures by all responsible for using them, looking forward to possible further revision and improvement. However, the procedure is not subject to change before the designated date. Some companies found during the war that procedures were changing so frequently that the result was one of retardation of work rather than progress. This may be worse than stagnation. "Scheduled" review of procedures seems an appropriate preventive of either of these conditions.

**Six Points of Communication Analysis.** The entire process known as *operation analysis* is principally the finding of all available facts about a given operation. It is accomplished by adopting a "questioning attitude" toward every part of the job and examining each part minutely.

The principle of adopting a questioning attitude as a means of educating oneself by uncovering facts is nothing new. It appears to be one of nature's laws that we learn by asking questions. Every child, after learning to talk, becomes a veritable question box, asking Why? How? What? Where? When? of every new thing its young mind or eyes dwell upon even momentarily. This is its way of learning. As a child grows to manhood he further develops his intelligence by questioning, but his questions assume a more logical pattern, and those who become truly great in every field of human endeavor are those who continue to question intelligently conditions or patterns about which they are uncertain or uninformed.

All of us realize that an almost infinite number of questions might be asked about even the simplest communication problem. Therefore it becomes mandatory that some systematic procedure for asking these questions be adopted if we are to be able clearly to analyze the problem and to cover all phases of the situation. If we were to approach this problem in a hit-or-miss fashion, it is possible that certain points—perhaps important ones—might be missed.

Therefore, to avoid wasted effort and to be certain that all important points are considered, we should keep clearly in mind certain factors that should be examined on every operation. These factors should be considered in the order of their likelihood of uncovering possibilities for improvement, and should be considered in detail whether the analysis is mental or written.

The problem of communication analysis is worthy of considerably broader treatment than is possible in this one chapter. Here we can attempt only to illustrate the scope of opportunities and suggest six of the much longer list of points or factors that should be considered in the analysis of communication problems.

1. Purpose of the operation or communication.
2. Survey of preceding and succeeding operation.
3. Functional requirements.
4. Type of form used.
5. Communication handling procedure.
6. Working conditions.

**Purpose of the Communication.** In every analysis of every problem the first and most important question to be asked is, "What is the purpose of the operation or communication?" Obviously, it is wasted effort to analyze all other phases of a problem, such as the type of equipment used in making the communication difficult to interpret, if it is later found that the communication in itself serves no worth-while purpose.

By questioning this point alone, perhaps the greatest improvements can be realized by the person analyzing communication problems. For many years, it has been almost a byword in industry and business to "Write—don't phone." Once one analyzes the time required to write a memo, send it by messenger, file it, and secure additional information that has not been included in the memo, it is obvious that writing memos is in most instances a costly, ineffective, and time-consuming procedure. By merely asking, "What purpose is served in writing the communication?" the answer may indicate that it is unnecessary to have the communication in written or semipermanent form.

Since business has almost completely disregarded the communication situation, many unnecessary communications are made daily by mere force of habit. One interesting use was found when a clerk repeatedly phoned a production scheduler to secure additional information to post on a pay-roll document. When the situation became chronic an investigation was made, and during the investigation it was discovered that the information she was securing by phone was unnecessary. The form for which she secured the information had been designed and installed several years previously. During the year a system change had been made, but in the interest of economy the form was not revised. For three years the pay-roll clerks had been patiently securing useless information merely because the space on the form remained unfilled.

It is important to consider the purpose of the operation, but the mere question, "What is the purpose of the operation?"—mentally framed—may not be suggestive enough to develop a thorough understanding of the matter. It is only when one begins to probe deeply that the real answer is obtained. For this reason, questions similar to the following list should be asked:

1. What is the purpose of the communication?
2. Are the results accomplished necessary?
3. What makes them necessary?
4. Is the call made through habit?
5. Could the information be secured elsewhere?
6. Could the purpose of the communication be accomplished better in another way?
7. Have conditions changed since the system or procedure was installed?
8. Is the communication made to cover up improper performance of a previous operation?

**Survey of Preceding and Succeeding Operations.** As stated before, no operation can be safely studied by itself, but must be regarded as a part of the entire process. The effect of any changes that are suggested must be considered in the light of the completed job. Only in this way can one be sure that the contemplated changes will be truly worth while.

The following questions are a few of the many that might be asked in regard to this point of the operation-analysis procedure:

1. Can the communication be eliminated by combining it with another communication or operation earlier or later in the process?
2. Can the communication be eliminated by changing the procedure?

3. Is the process sequence the best possible?

4. Can the information contained on a form be transmitted by telephone with no loss of effectiveness or permanency?

5. If a form is used, can the operation of filing the copy be eliminated by use of a telephone for reference to the original copy in a central file?

**Functional Requirements.** Ineffective communication procedures are often the result of improperly functioning systems, forms, and equipment. A typical example is the use of information duplicated by several different methods, of which some copies are faint, difficult to read, or often entirely illegible. When an operator receives such a copy and cannot interpret it, a telephone call is probably made to one of several persons for interpretation of the undiscernible information. Another case might be the use of a form without space for certain necessary information. Several questions that might be raised about this point would be

1. What are the functional requirements of this communication?

2. Is the telephone used to cover up the ineffectiveness of a written communication?

3. Can the written form be quickly interpreted?

4. Is unnecessary information included in the communication?

5. If the unnecessary information is detail, would a telephone call be sufficient to convey the communication?

6. Is the communication worded in a manner easy to understand?

7. Can all the necessary information be translated or received in one communication?

**Type of Form Used.** Since most written communications in industry are supplementary to well-established systems or procedures that demand that certain information always be provided, a prepared form with identified spaces for all necessary information is usually constructed to make interpretation of the communication easier and to reduce the possibility of omissions of necessary information. Use of forms, however, is greatly abused in a great many industries through insufficient use and also through too wide a use. Then, too, when systems and procedures change, forms tend to become obsolete in that they either have more information than is necessary to ensure successful operation of the changed system, or perhaps insufficient information. In the interest of economy and from force of habit, many businesses have been loath to change the form design and scrap the surplus form supply.

When forms are used in conjunction with a telephone call, it is imperative that they be readily available, easily interpreted, and

easy to file and obtain from a file. This is especially important when they are used in connection with toll calls. If sufficient information is not present, confusion may result during the telephone conversation and as a result another toll call may be necessary. If the form is difficult to handle, as is a large sheet of onionskin paper, for instance, time may be lost in obtaining it from the file while the call is being held. The size and shape of the form may necessitate use of large, unwieldy file cabinets that must be located at some point distant from the telephone location at which they are most used. Thus, if the toll caller requests information that can be found only on the form, the only alternative is to rise and walk to the files to obtain it, meanwhile seriously delaying the call and adding to the toll charges.

These are but a few of the many ways in which an inefficient form can seriously disrupt the effectiveness of communication. And the following questions are only a few of the many that might be asked in analyzing this point.

1. Is the form necessary or would a telephone call be sufficient?
2. Is the form easily handled and filed?
3. Is the information recorded clearly and in proper sequence?
4. Is the size and shape of the form such that it can be easily filed adjacent to the point where it is most used and referred to?
5. Is all necessary information included?
6. Is unnecessary information included?
7. Could the design of the form be changed to combine two or more forms into one?
8. Could a teletypewriter or other specialized equipment be used advantageously if there are many copies to be made and widely distributed?

**Communications Handling Procedure.** It is undoubtedly true that perhaps the greatest cause of ineffective communications is improper handling, whether verbal or written. In most written-communication work, the time for writing and for reading a communication is only a fraction of the time required to handle it. A form may be written in one minute and read in one minute, but the time lost in waiting for its pickup by the messenger and later delivery usually consumes from one to twenty-four hours within the plant itself. In the use of the telephone, too, the time of handling the communication is generally greatly in excess of the actual time spent in making the verbal communication. For example, in calling a foreman in a shop where the clerk who answers must walk 50 to 100 feet to notify him that he is wanted, the time spent in getting the foreman and his travel

to the telephone may be many times greater than the time spent in transmitting the information.

Material handling on the floor of a manufacturing plant falls into the same category and in about the same proportions. The time spent in notifying and then waiting for a craneman or electric trucker to come to the workstation to bring or move material, the time spent waiting at a tool crib or stock room, all are greatly increased because of improper communication. An entire textbook could be, and in fact has been, written about this one point alone. Since it is so important, it should always be considered in minute detail. A few of the many questions that might be asked in analyzing this point would be:

1. Is the time spent in handling the communication large in proportion to the time spent in making the communication?
2. Is the telephone being called excessively busy, necessitating frequent dialings, walking from workstation to telephone, etc.?
3. Would installation of additional telephone service reduce the waiting time through preordering or preplanning?
4. Could bells or lights be used to notify the person that he is wanted on the telephone?
5. Is adequate telephone service provided to eliminate a chronic "busy" condition?
6. Would prompt delivery of the information improve the operation of the department receiving the communication?

**Working Conditions.** Work is done most effectively under good comfortable working conditions, and this is especially true of communications. Certain conditions, such as excessive noise or lack of light, make the act of writing, dictating, or telephoning difficult, inaccurate, and time-consuming.

Up to this point we have considered factors involving human effort and ingenuity to operate these methods and obtain the desired results. Since working conditions affect human effort and the equipment involved, we must seriously consider this element if we are to obtain maximum effectiveness.

To convey or interpret a communication effectively, whether written or verbal, one must be able to use his senses of hearing and seeing at maximum effectiveness and must be able to speak or write clearly and distinctly. Working conditions in the shop or office frequently make this difficult if not impossible. Anyone who has attempted to understand a telephone message transmitted over an unshielded telephone in a noisy foundry or drop-hammer shop can

well understand the difficulty and delay to be encountered when working conditions are bad. Then, too, attempting to decipher a greasy or dirty form in a dimly lighted location is a "by guess and good judgment" proposition in most cases.

The following questions might be asked relative to improving working conditions with a resultant increase in communication effectiveness:

1. Is the area excessively noisy, and if so can it be remedied by rearrangement of floor space and equipment?
2. Would accoustical material in floors, ceiling, and walls reduce noise sufficiently?
3. Is there an excessive amount of movement by office workers (walking between desks, files, etc.)? If so, would additional telephones at desks, added messenger service, or conveyors effectively reduce this movement and the resulting noise and confusion?
4. Is the light inadequate, making reading or interpretations of drawings, blueprints, forms, or letters during a telephone conversation difficult?
5. Is the space on which messages might be written during a conversation dirty, oily, or rough, making the recording difficult and later illegible?

### CASE 20. COOPERATION BETWEEN SALES AND PRODUCTION DEPARTMENTS

*Boston Machine Company.*[1] Some time ago, the field representative of a manufacturer of production-control equipment was engaged by the Boston Machine Company to install a scheduling control system in its Boston plant. On completion of the installation, the representative felt that it was operating in a highly satisfactory manner. However, recently he received a call from the concern to the effect that trouble had developed, and he was asked to investigate.

He found that at the present time, when an order is received from a customer, the manufacturing orders for the various parts and subassemblies are issued; raw materials, castings, etc., are ordered from vendors; and the parts are carefully scheduled throughout the respective operations so that effective control of production can be maintained. The trouble, it appears, arises in the sales department. When the salesman secures the order from the customer, the customer naturally specifies delivery as soon as possible and very often asks for delivery several days or weeks before it is possible for the Boston

[1] Name fictitious.

Machine Company to make delivery. The salesmen, in their enthusiasm over taking the order and in their effort to keep the customer pleased, pick delivery dates "out of the air" and make definite promises. When the production department receives the order and it becomes apparent that the date promised by the sales department cannot be maintained, this fact is invariably pointed out to the sales department. Instead of cooperating, the sales department usually insists that the delivery date be kept even if it means rearranging the schedule and sidetracking the orders of other customers. Thus it becomes necessary to revise schedules previously set up in order to meet one of these otherwise impossible delivery dates. It also means that although the concern makes a friend of one customer by maintaining the delivery as promised, it must at the same time break the promises made to several other customers. In addition, this continual reshuffling and rescheduling of orders is very expensive, and costs are mounting. The field representative is under the impression that the sales department of the Boston Machine Company does not understand production problems, nor does it appear to want to understand them. Consequently there is very little cooperation between the two departments.

### Preparatory Question

If you were the field representative of the firm making production-control equipment, what would you recommend to the Boston Machine Company to eliminate this trouble?

### CASE 21. COORDINATING A CHANGE IN PLANT FACILITIES

*General Brands, Inc.*[1] General Brands, Inc., is a manufacturer and wholesale distributor of packaged foods. Its main plant, located in the Midwest, specializes in preserves, candy, cookies and crackers, extracts, coffee, and salad dressings. Its business is divided almost equally between the sale of its own manufactured products and the job distribution of the branded products of other manufacturers.

The main plant is a four-story structure. The activities are divided roughly into manufacturing and packaging on the second and third floors, storage on the fourth floor and, to some extent, on the first floor. The first floor is also used as the distribution point for assembling and shipping orders to jobbers and retailers. Warehouse areas on the fourth and first floors are departmentalized according to type of goods and also according to complete and broken packaging.

[1] Name fictitious.

Until recently a cumbersome system was used in the filling of orders. When an order was received from a customer, it was broken down according to the departmental warehouse areas, and a slip was issued to each warehouse concerned listing the goods required from that department. The order clerk in each department obtained the goods listed on his slip, placed the packages on a hand truck, and wheeled them over a long and devious route, down the elevator if necessary, until he reached the assembly area, where he deposited the goods. Then he "dead-headed" his hand truck back to his originating department for another load.

Several difficulties were encountered with this procedure. It was costly, articles in a particular order became lost at the assembly point, sorting of the orders was difficult, and the men filling the orders spent a great part of their time "dead-heading" the hand trucks back to their departments and waiting for the elevator to take them from one floor to another.

A young production executive in the concern asked and received permission to invite a manufacturer of conveyor equipment to make a study of the situation. Finally the two were able to convince the officials of General Brands that a completely conveyorized plant would solve the above difficulties, greatly lower the cost, and make for much quicker filling of orders.

By dint of some unique engineering, the conveyor has been designed so that goods in any department that are put on the order-filling conveyor belt automatically find their way to the assembly point. This is facilitated by the use of gravity rolls, chutes, automatic finger-type elevators, a "rotary traffic circle" at the assembly point, with a series of short switching belts. In the warehousing areas, where receiving and order-filling are carried on simultaneously, upper and lower belts have been installed for receiving and order-filling, respectively. Thus goods automatically come into these areas on the upper belt from the manufacturing sections (products purchased from other packaging houses come directly from the receiving room) and are stored away. When an order is received from the customer it is broken down by warehouse area as before, but each order clerk merely assembles the goods required from his area and places them on the lower conveyor belt. When they arrive at the "rotary traffic circle" in the assembly area, the complete order is assembled and is then conveyorized to the loading platforms and loaded directly from conveyor to truck or railroad car, as the case may be. The change, incidentally, has enabled the concern to reduce the number of men responsible for handling and distributing the material from

115 to 60. Those displaced have been absorbed in other departments.

However, after the conveyors were installed, a rather difficult problem arose during the change-over. The plant superintendent, who was rather skeptical of the use of the conveyors anyway, argued that the only way to make the change-over was to stop the old method one night and start all the conveyors at once the next morning. He contended that, although this might cause a little confusion at first until the difficulties could be eliminated, it would make for a quick change-over and would minimize the disruption of the distribution schedules. Furthermore, the new system called for considerable rearranging of stock within the storage areas and from one area to another. The superintendent contended that although it might result in less confusion to have the goods in their new and proper location when the conveyors started, it would require that goods be carted from one area to another by hand truck, whereas, if the company waited until after the change-over of equipment, the conveyors could be used to facilitate the rearranging of goods.

The plan advanced by the superintendent was adopted, and on the morning designated the complete conveyor system went into use. Several difficulties soon developed. First, the men were not familiar with their duties, and the number of men had been reduced to almost the number estimated as ultimately needed. Second, the superintendent's skepticism caused him to give the conveyor every opportunity to prove that it would not work. Third, the fact that the goods were not in the places where they were ultimately to be assigned caused much confusion, since the type of conveyor in each section was designed to handle loads of certain weights and shapes. With goods not in their proper places, some of the conveyors were improperly loaded.

Soon after the conveyors were started, the goods began to pile in at the assembly area from all departments. The inexperienced crew at that point soon fell behind in the sorting of orders, with the result that goods began to "back up" on the conveyors. Heavy canned goods came shooting down the gravity rolls and crashed into fragile packages of crackers and candy with rather dire results. It so happened that a rather sizable order of liquor was to be sent out that morning. Large cases of liquor retailing at $75 a case came rolling into the assembly area and backed up on the conveyor. Finally the "train" of these cases buckled, and five cases crashed to the floor. At this point the superintendent dashed for the controls and stopped the conveyor.

### Preparatory Question

Assume that you are the young production executive who aided in the development of the conveyor system and that you arrived on the scene at the assembly area just in time to see $375 worth of liquor spreading about the floor. What steps would you recommend be taken to coordinate the change-over? In retrospect, what should have been done?

## CASE 22. COMMUNICATIONS PROCEDURES

*The J. P. Alfred Company.*[1] The maintenance force of the J. P. Alfred Company numbers from 60 to 70 men. The department services a total of 1,500 metalworking machines in addition to other manufacturing and office apparatus.

The maintenance engineer in charge of the maintenance department approves schedules on all repair jobs. In case of machine breakdowns or other incidents calling for the services of a maintenance repairman, the procedure is to call the maintenance engineer by telephone regardless of the relative urgency of the matter. If the maintenance engineer is not at his telephone, as is usually the case since he spends most of his time with the repair crews, he is paged on the code-call system. This, of course, makes it necessary for him to leave the job he is supervising, locate a telephone, and answer the call. Delay in maintenance work results.

### Preparatory Question

Suggest one or more improvements in the procedure for reporting, approving, and supervising maintenance work.

## CASE 23. COORDINATING INTERNAL ORDERING PROCEDURE

*The J. C. Buckley Instrument Company.*[1] The J. C. Buckley Instrument Company, manufacturing electrical measuring instruments, has recently moved into a new high point in business activity. This is due, it seems, to at least a temporary upturn in general business conditions.

With this sudden influx of business, the company is encountering difficulty in keeping material on hand to meet production needs. The management of the company has been advised to keep material and finished goods inventory at a minimum because of the uncertainty of market conditions and the probability of declining prices.

[1] Name fictitious.

As an alternative to increased inventories, the company is analyzing its material procurement procedures for possible improvements in control. It has found that the internal procedure for the handling of orders is causing considerable delay. The procedure is as follows:

1. Order from the customer is received by the sales department.
2. Order is sent by the sales department to the production-control department by the internal mail system.
3. The production-control department checks material on hand by telephoning the inventory-control department.
4. Inventory control telephones to the stock room to verify its records.
5. Inventory control reports to production control whether material requested is in stock or must be ordered.
6. Production control issues a requisition by the internal mail system to the purchasing department authorizing the purchase of needed material.

Analysis shows that telephone calls require about three minutes each. Internal mail is picked up and delivered four times each day; twice in the morning and twice in the afternoon.

## Preparatory Question

Show possible improvements in the steps of the internal ordering procedure listed that would tend to speed delivery of essential information to the purchasing department.

# APPENDIX A

# WRITTEN STANDARD PRACTICE

Reference has been made at several points to the use of standard practices and procedures as an aid to the control of production. The necessity for standard practices demands that means be established whereby all people responsible for the activities of the various departments are (1) fully instructed regarding the practices that have been adopted as standard and (2) appreciative of the importance of the universal acceptance of these standards until such time as a change can be agreed upon by the company as a whole. In large companies engaged in continuous manufacturing, the efficiency of separate operations and the coordination of these operations may require absolute adherence to the standard practices of the company.

Through the courtesy of the United States Rubber Company, Footwear Plant, Naugatuck, Conn., a small portion of their manual on written standard practice is presented as an illustration of a means toward standardization. Parts of two sections are given: (1) Written Management Classifications, which briefly explains the types of management reports and instructions that are issued in written form, (2) Index—Production Control W.S.P., listing the topics related directly to production control on which standard practice bulletins have been prepared, and (3) a sample bulletin showing the nature and general organization of subject matter.

It should be noted that these bulletins are written by various people throughout the departments. This spread of responsibility for the preparation and presentation of standard practices tends to stimulate a more cooperative attitude within the personnel of the different departments, in the attempt to formulate standards.

It should also be noted that a date is set on which each bulletin should be reviewed and revised. This provision is intended as a means toward the continuous improvement of standard practices. Shortly before the review date, the bulletin is called to the attention of the supervisory staff, with a request for suggestions regarding possible improvements.

Bulletins are distributed throughout the plant to each member of the managerial staff, who files them in a loose-leaf binder, thus making them readily available for reference.

| Part 1<br>**WRITTEN STANDARD PRACTICE**<br>Naugatuck Footwear Plant | Staff<br>Supts<br>Foremen |
|---|---|

SUBJECT: Written Management—Classifications W.S.P. No. FM3-1

DATE: Oct. 7, 1940

| Prepared by | Number of sheets | Approved by |
|---|---|---|

Department or persons to whom this applies

Refer to:

Supersedes FM 3-1 dated 5/26/38

I. It is the policy of the company that all instructions, procedures, methods, and information be issued in written form as illustrated by:
   *A*. Written standard practice.
      1. Statements of policy, principles, and procedure that may form the basis for supplementary instruction sheets and manuals.
         Examples:
         *a*. Policies.
            (1). Policies W.S.P. FM 4.
            (2). Wage payment W.S.P. Pl. 11.
         *b*. Management principles.
            (1). Meeting principles W.S.P. FM 2.
         *c*. Procedures.
            (1). Management procedures FM 3.
            (2). Employment procedures IR 1.
      2. Instructions to operators and detailed specifications should not be included in W.S.P. (see W.S.P. FM 3-4*c*).
      3. See W.S.P. FM 3-2*a* to *f*.
   *B*. Change orders.
      1. The medium by which new or changed information regarding tickets, construction die or method is authorized and circulated to all executives concerned.
      2. See W.S.P. FM 3-3.
   *C*. Bulletins.
      1. Written information issued for certain conditions, operations, or periods to be thrown away when no longer needed, usually within a month.
         *a*. Education information and minutes.
         *b*. Shutdown notices.
         *c*. Schedules.
         *d*. Organization notices.
      2. Routine reports issued on a definite schedule to indicate necessary action or provide a factual record of accomplishment.
         *a*. Scrap analysis.
         *b*. Savings forecasts, etc.
         *c*. Cost reports.

**WRITTEN STANDARD PRACTICE.**—(*Continued*)

*D.* Job manuals.

1. Written instructions covering the duties and procedures of what constitutes a specific job.
   *a.* Example: Supervisors' manuals (see W.S.P. FM 3-4).
2. They include:
   *a.* Job analysis.
      (1). An outline of the responsibilities of a specific job.
      (2). See W.S.P. FM 3-4*a*.
   *b.* Half-hour schedules.
      (1). Daily work schedules that budget the time of executives.
      (2). See W.S.P. FM 3-4*b*.
   *c.* Instruction sheets.
      (1). Detailed instructions for clearing how a job is to be carried out.
         (*a*). Example: compound-formulas sheets.
      (2). Detailed specifications or records for materials, equipment, etc.
         (*a*). Example: fabric code.
      (3). See W.S.P. FM 3-4*c*.
   *d.* Pertinent copies of W.S.P.

**Part 2**
EER April 18, 1940
**INDEX—PRODUCTION CONTROL W.S.P.**

WHN
Staff
Supts
Foremen

| P.C. No. 1 | Product specifications, materials, composition, gauges, findings, etc. | Author | Will review |
|---|---|---|---|
| 1-1 | Product development and clearance for commercial production | EJG | 4/1 |
| 1-1*a* | Change-order procedure | EER | 8/15 |
| 1-1*b* | Change orders—construction, die and pattern and ticket | EJG GRL | 8/1 |
| 1-2 | Fabric code | RHH | 9/15 |
| 1-3 | Top fabric code—Fabric Shoe Mill | EJG | 7/24 |
| 1-3*a* | Calender coated-stock code—Fabric Mill | EJG | 8/1 |
| 1-4 | Thread specifications for waterproof footwear | EJG | 7/1 |
| 1-5 | Thread specifications for fabric footwear | EJG | 10/1 |
| 1-6 | Abbreviations for ticket construction detail | EJG | 9/15 |
| 1-7 | Kwik fasteners—code numbers and usage | EJG | 11/1 |
| 1-8 | | | |
| 1-9 | Trim stock code—Fabric Shoe Mill | EJG | 7/15 |

| P.C. No. 2 | Scheduling capacities, lasts, molds, stamping, dies, rolls, etc. | Author | Will review |
|---|---|---|---|
| 2-1 | New types and new styles—mill clearance procedure—waterproof-fabric shoes and bathing shoes | ETF | 6/1 |
| 2-1*a* | Inspection of new lasts | GEA | |
| 2-2 | Corresponding last names | EJG | 8/1 |

INDEX—PRODUCTION CONTROL W.S.P.—(*Continued*)

| P.C. No. 2 | Scheduling capacities, lasts, molds, stamping, dies, rolls, etc. | Author | Will review |
|---|---|---|---|
| 2-3 | Lasts—standard model numbers | BBC | 6/1 |
| 2-4 | Lasts—standard measurements | CEH | 6/1 |
| 2-4*a* | Lasts—standard oxford back gauges | BBC | 11/1 |
| 2-5 | Ticket scheduling within last limitations | ETF | 5/1 |
| 2-6 | Lasts—breakage, repairs, and replacement control | ETF | 6/1<br>12/1 |
| 2-7 | Lasts—selective check—wood and metal | ETF | 3/1<br>9/1 |
| 2-8 | Standard upper and soling rolls | EJG | 8/31 |
| 2-9 | Molded-label identification chart | EJG | 10/1 |
| 2-10 | | | |
| 2-11 | Dipping form—last identification | EJG | 10/1 |

| P.C. No. 3 | Production, planning and scheduling—analysis, assignments, in-process, time, and inventories | Author | Will review |
|---|---|---|---|
| 3-1 | Procedure for maintaining supply of impervious insoling | JBH | 10/1 |
| 3-1*a* | Mixing and refining of leather-gum stock—local mill room and Naugatuck Chemical Co. | JBH | 10/1 |
| 3-2 | In-process schedule and procedure—waterproof molded heels | JBH | 9/1 |
| 3-2*a* | In-process schedule—double-shift cutting—waterproof outsoles | JBH | 2/1 |
| 3-2*c* | In-process schedule—rubber Gaytee lining (double-shift basis) | JBH | 3/1 |
| 3-2*d* | In-process schedule—sponge arch and heel cushion | JBH | 9/1 |
| 3-3 | Filling procedure—consolidation and schedule | GRL | 2/1<br>6/1 |
| 3-3*a* | Follow-up cycle identification of filling brackets | JBH | 6/1<br>12/1 |
| 3-3*b* | Cyclone schedule—Fabric Shoe Mill | GRL | 12/1 |
| 3-3*c* | Rush filling schedule, 5- 4- 3-day week—waterproof | GRL<br>JBH | 5/1<br>10/1 |
| 3-3*d* | Cyclone ticket procedure—waterproof | GRL<br>JBH | <br>6/3 |
| 3-4 | | | |
| 3-5 | Cancellation request and procedure waterproof | JBH | 4/1 |
| 3-5*c* | Dropping cases in packing room | ETF | 4/1<br>12/1 |
| 3-6 | Carton-ordering procedure for footwear—waterproof, fabric shoe and bathing shoes | ETF<br>GRL | 5/1<br>11/1 |
| 3-6*b* | Carton procedure for lacking cases—waterproof, tennis, sport shoes, strollers and bathing shoes | ETF | 8/1 |

**INDEX—PRODUCTION CONTROL W.S.P.- (*Continued*)**

| P.C. No. 3 | Production planning and scheduling—analysis, assignments, in-process, time, and inventories | Author | Will review |
|---|---|---|---|
| 3-7 | Lot preparation and control—fabric shoe tickets | JBH | 8/15 |
| 3-8 | | | |
| 3-9 | Trouble reports | EER | 9/15 |
| 3-10 | | | |
| 3-11 | In-process schedule—E.S. cutting and stitching | JBH | 10/1 |
| 3-12 | | | |
| 3-13 | Ordering rubber-ink labels from Naugatuck Chemical Co. | JBH | 6/1 |
| 3-14 | | | |
| 3-15 | Order of make and bracket-numbers control—waterproof mill | JBH | 2/15 |

| P.C. No. 4 | Merchandise control (Accounting classification grouping, damaged disposition, etc.) | Author | Will review |
|---|---|---|---|
| 4-1 | Lacking cases, branch stores | ETF | 9/1 |
| 4-2 | | | |
| 4-3 | Lacking case report—waterproof, fabric, and bathing shoes | ETF | 4/1 |
| 4-3*a* | Lacking case procedure—mill handling waterproof | BFG | 4/1 |
| 4-4 | Classification of factory-damaged report 2662 | ETF | 4/1<br>10/1 |
| 4-4*a*2 | Colchester brand waterproof footwear 1934—application of "seconds" on shoes—cartons and cases | ETF | 9/15 |
| | Factory-damaged disposition (NOTE: Separate specifications are listed for each of 29 different brands of production. Numbers 4-4*a*3 to 4-4*f*3, inclusive.) | ETF | |
| 4-4*g* | Stock numbers—Colchester-brand waterproof | WJG | 6/15 |
| 4-4*h* | Factory-damaged disposition—Woonsocket, dry-shod and corresponding specials; brands of waterproof | ETF | 2/15 |
| 4-4*i* | Factory-damaged disposition | ETF | 9/15 |
| 4-4*j* | Export factory damaged—packing and invoicing | ETF | 9/15 |
| 4-4*k* | Returns—disposition and control | ETF | 2/15 |
| 4-4*kl* | Returns—inspection | ETF | 1/1<br>6/1 |
| 4-4*l* | Mismates selection, disposition and control—waterproof and fabric shoe | ETF | 1/1 |
| 4-5*a* | Footwear-production reports | GRL<br>ETF | <br>10/2 |
| 4-5*a*1 | Footwear-production reports—lacking case detail | ETF | 10/1 |
| 4-5*b* | Production-efficiency record | ETF | 10/1 |

**INDEX—PRODUCTION CONTROL W.S.P.**—(*Continued*)

| P.C. No. 4 | Merchandise control (Accounting classification grouping, damaged disposition, etc.) | Author | Will review |
|---|---|---|---|
| 4-5*b*1 | Production records—making and packing departments—bracket check | SG | 9/1 |
| 4-5*f* | Sponge-windlace production record | GAC | 7/15 |
| 4-6 | | | |
| 4-7 | | | |
| 4-7*a* | Surplus-shoe disposition and salvage of damaged goods | ETF | 4/1 |
| 4-7*b* | Handling perfect and damaged odds | BFG | 4/1 |
| 4-7*c* | Perfect-half-pair disposition—Beacon Falls waterproof, tennis and bathing shoes | ETF | 6/1 |
| 4-7*d* | Odd-shoe control—ordering, storing, mating, and disposition | ETF | 4/1 |
| 4-7*e* | Half-pair-mating-cost formulas—perfects—factory-damaged thirds | JJW | |
| 4-8 | | | |
| 4-9 | Factory-damaged disposition waders | ETF | 1/30 |
| 4-9*a* | Returned merchandise, handling and accounting procedure | ETF | 2/15 |
| 4-9*a*1 | Accounting procedure—Bathing shoes and sponge rubber WHO'D | | |
| 4-9*b* | Return merchandise, Beacon Falls, testing and questionable construction | ETF | 6/15 |
| 4-10 | | | |
| 4-11 | Removal of merchandise from warehouse for inspection | ETF | 4/15 |
| 4-12 | | | |
| 4-13 | | | |
| 4-14 | Authorization—special footwear items | BBC | 10/15 |
| 4-15 | Merchandise group classification—waterproof, fabric, bathing shoes, beach strollers and sponge | ETF | 3/15<br>9/1 |
| 4-16 | Comparative brand names of waterproof footwear | EJG | 10/1 |
| 4-17 | Stock numbers—United States | PM | 10/1 |
| 4-18 | Shoe forms—returned | GRL | 10/1 |

| P.C. No. 5 | Material estimates vs. production estimates (raw-material requirements) | Author | Will review |
|---|---|---|---|
| 5-1 | | | |
| 5-2 | | | |
| 5-3 | Binding scrap control—Fabric Shoe Mill | JBH | 10/1 |

INDEX—PRODUCTION CONTROL W.S P.—(*Continued*)

| P.C. No. 6 | Packaging procedure (cartons, cases, scale runs, exterior description) | Author | Will review |
|---|---|---|---|
| 6-1*a* | Carton packing, shoes and rubber gaiters | ETF | 7/1 |
| 6-1*b* | Packing—fabric shoes | GDG | 7/1 |
| 6-1*c* | Packing—gum shoes | HNB | |
| | | ETF | 7/1 |
| 6-1*d* | Packing gaiters and arctics | GDG | 7/1 |
| 6-1*e* | Packing boots | GDG | 7/1 |
| 6-1*f* | Packing specifications—cartons—shipping containers | GDG | 7/1 |
| 6-1*g* | Packing bathing shoes and strollers | GDG | 10/1 |
| 6-1*h* | Packing lumbermen | GDG | 7/1 |
| 6-2 | | | |
| 6-3 | Case coding—waterproof footwear | ETF | 6/1 |
| | | | 12/1 |
| 6-3*a* | Case coding—tennis and sport shoes | ETF | 10/15 |
| 6-3*b* | Case label—application | ETF | 8/1 |
| 6-3*b*1 | Case label—designation of pairs lacking and stamp location | ETF | 9/1 |
| 6-3*b*2 | Case label—application—reused cases | ETF | 3/1 |
| 6-7 | Carton- and case-label printing | ETF | 4/1 |
| | | | 10/1 |
| 6-8 | Carton-stamping fabric shoe | ETF | 12/1 |

| P.C. No. 7 | Customer service (special handling shipping, traffic, complaints) | Author | Will review |
|---|---|---|---|
| 7-1 | Order follow-up procedure—waterproof, fabric shoes, bathing shoes, sponge products | ETF | 4/1 |
| | | | 9/1 |
| 7-2 | | | |
| 7-3 | | | |
| 7-4 | Short case packing | ETF | 9/15 |
| 7-4*a* | Lacking case tolerance—extreme-sized stock | GRL | 1/15 |
| 7-4*b* | Lacking cases—combining of sizes | ETF | 10/15 |
| 7-5 | | | |
| 7-6 | Customers' complaints—service and quality | EER | 9/15 |
| 7-7 | | | |
| 7-7*a* | Export packing—bulk and bale containers | GRL | 10/15 |
| 7-8 | Schedule—sample-line development | JER | 1/15 |
| 7-9 | Finished-goods shipment—procedure—waterproof and fabric footwear | ETF | 6/1 |
| 7-10 | Sponge-rubber-sample follow-up | CEW | 1/30 |

## Part 3

### WRITTEN STANDARD PRACTICE
Naugatuck Footwear Plant

Sent to:

SUBJECT: In-process Schedule and Procedure—Waterproof Molded Heels

W.S.P. No. P.C. 3-2 (replaces 3-2*b*) 3-8

DATE: Mar. 15, 1938

| Prepared by________ (schedule supervisor) | Number of sheets | Approved by________ (department head) |
|---|---|---|

Department or persons to whom this applies: Heel-molding, cementing, and fitting departments

Refer to:

The schedules or the molding, trimming, and buffing of waterproof heels in the Fabric Shoe Mill; also their cementing and fitting in the Waterproof Mill are as follows:

I. Schedule for tubing, slicing, molding, etc., in fabric shoe molding department.
  *A*. Stock tubed 5 days ahead on third shift.
  *B*. Tubes sliced 4 days ahead on first shift.
  *C*. Mold heels starting at 3 P.M. on the second shift—4 days ahead of the final-assembly day.
    1. Molding of heels will be completed by 3 P.M.—3 days ahead of the final-assembly day.
    2. Odd stock to be molded on the second shift—3 days ahead of the final-assembly day.
  *D*. Trim and buff heels, starting at 7 A.M. on the first shift—3 days ahead of the final-assembly day.
    1. Trimming and buffing of heels will be completed by 3 P.M.—3 days ahead of the final-assembly day.
    2. Odd stock to be trimmed and buffed as soon as possible after the molding.
  *E*. Check and count heels, starting at 7 A.M. on the first shift—3 days ahead of the final-assembly day.
    1. Checking and counting of heels will be completed by 7 A.M.—2 days ahead of final-assembly day.
    2. When heels are checked and counted they are to be placed in separate containers by model number, color, and size. No one box to contain more than one kind of heel unless they are divided by separators.
  *F*. Heel ticket complete with odd stock to be in building 216, second floor by 8 A.M.—2 days ahead of the final-assembly day.
    1. Trucking department will pick up the heels in the molding department between 7 and 8 A.M.—2 days ahead of the making for delivery to building, 216, second.
    2. Example of schedule: Trucking department will pick up the heels Tuesday A.M. between 7 and 8 A.M. for the following Thursday's final assembly.

II. Schedule for cementing and fitting molded heels in waterproof outsole cutting department.

**WRITTEN STANDARD PRACTICE**—(*Continued*)

*A*. Heels received complete from molding department at 8 A.M.—2 days ahead of the final-assembly day.

*B*. Cement heels starting at 8 A.M. on the first shift—2 days ahead of the final-assembly day.

  1. Cement by model number and color so that picking heels into complete brackets will be simplified.

*C*. Pick and count heels into units of brackets on the ticket, starting at 10 A.M.—2 days ahead of the final-assembly day.

  1. Store brackets at heels at fitting belt in same order that heels will be fitted to outsoles.
  2. Any shortages or odd stock to be ordered from the molding department as soon as possible and to be delivered to the fitting department by 8 A.M. the following morning.

*D*. Fit heels to cut holes, starting at 10 A.M. on the first shift, 1 day ahead of the final-assembly day.

  1. Approximately two-thirds of each first shift making conveyors to be cut and fitted the day before the final-assembly day and the balance to be completed by 10 A.M. on the day of assembly.

III. Miscellaneous.

*A*. Ticket department must observe the mold limitations as set, because they are based on 24-hour periods.

*B*. The order department will notify the analysis department of all orders received, the production and the final-assembly dates on items requiring special heel compounds, such as 603, 623, etc., in order that quantities of these mixed stocks may be kept at a minimum.

# APPENDIX B

# PRODUCTION-CONTROL FORMS

(Presented as an aid to the reader in understanding continuity and functional relationship of control forms when adapted to the needs of a single industry.)

## CHASE BRASS AND COPPER COMPANY, WATERBURY, CONN.

Description of forms and their uses, as of 1942, prepared by W. B. Bryan, production-control manager, Chase Brass and Copper Company

The Chase Brass and Copper Company has a Kardex file containing a card for every customer. As orders are received, the date received, date of order, customer's

| DATE RECEIVED | DATE OF ORDER | CUSTOMER'S ORDER NO. | REGISTER NUMBER | MATERIAL | SENT TO |
|---|---|---|---|---|---|
| | | | | | |

FIG. 42.

order number, register number (which is the branch office order), kind of material, and place the order is sent are listed. The last column is not filled in if the order takes its regular routine course to the production department for entering tickets in the mill. If it is held at any point, such as at the credit department, regarding credit, or at the sales department, regarding price, then this column is filled in. This is merely a record to show that an order has actually been received (see Fig. 42).

The ticket shown in Fig. 43 is sent to foreman of the sheet mill. It either draws semifinished stock from the stores department or, if the stock is depleted, has the material cast. See Fig. 57 for store report of the stock on hand and Fig. 54, requesting material cast.

**SHEET PLANT ORDER**

ENTIRE TOTAL CU. < > B 2700
TOTAL ENT. TER. PLANT
CUST. ORD. NO. DATED ENTERED SHIP

BARS SIZE ALLOY
LBS. PCS. FT. WIDTH GA. TEMPER
PROD. TOL. LENGTH

BILL TO
SHIP TO
ACCT. OF B/L
VIA.

| DATE | ROLL | ROLLER | FROM | TO | PASSES | DATE | ROLL | ROLLER | FROM | TO | PASSES | SHIPPED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | DATE |
| | | | | | | | | | | | | LBS. |
| | | | | | | | | | | | | PCS. |
| | | | | | | | | FINISHED BY | | | | |

FIG. 43.

The ticket shown in Fig. 44 is sent to mill foreman, together with the plant order. The ticket is used by promise clerks in the mill to follow up material.

**SHEET PROMISE TICKET**

ENTIRE TOTAL CU. < > B 2700
TOTAL ENT. TER. PLANT
CUST. ORD. NO. DATED ENTERED SHIP

BARS SIZE ALLOY
LBS. PCS. FT. WIDTH GA. TEMPER
PROD. TOL. LENGTH

BILL TO
SHIP TO
ACCT. OF B/L
VIA.

FIG. 44.

The copy shown in Fig. 45 is filed in the production department by the promise date. In this way, it can be told at all times how many promises are open on a given date.

**SHEET MEMO**

ENTIRE TOTAL CU. < > **B** 2700
TOTAL ENT. TER. PLANT
CUST. ORD. NO. DATED ENTERED SHIP

BARS SIZE ALLOY
LBS. PCS. FT. WIDTH GA. TEMPER
PROD. TOL. LENGTH

BILL TO
SHIP TO
ACCT OF B/L
VIA

FIG. 45.

The ticket shown in Fig. 46 is kept in the production office and is filed by account number (account numbers are arranged alphabetically). Progress is noted on this sheet every day as the order progresses through the mill. See Fig. 59, the sheet-mill machine-and-scale ticket, from which this information is derived.

**SHEET PROGRESS SHEET**

ENTIRE TOTAL CU. < > **B** 2700
TOTAL ENT. TER. PLANT
CUST. ORD. NO. DATED ENTERED SHIP

BARS SIZE ALLOY
LBS. PCS. FT. WIDTH GA. TEMPER
PROD. TOL. LENGTH

BILL TO
SHIP TO
ACCT. OF B/L
VIA

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| MACHINE | | | | | | | | | | |
| DATE | | | | | | | | | | |
| GAGE | | | | | | | | | | |
| MACHINE | | | | | | | INSPECTED | PACKED | SHIPPED | |
| DATE | | | | | | | | | BILLED | |
| GAGE | | | | | | | To Shipping Room | | WEIGHT | |

FIG. 46.

The copy shown in Fig. 47 is sent to the record department and is used for punching the tabulating cards.

**SHEET RECORD**

ENTIRE TOTAL
TOTAL ENT.
CUST. ORD. NO. DATED
CU.
TER.
ENTERED
< >
PLANT
SHIP
B 2700

BARS
LBS. PCS. FT.
PROD.
WIDTH
TOL.
SIZE
GA.
ALLOY
TEMPER
LENGTH

BILL TO
SHIP TO
ACCT. OF
VIA.
B/L

FIG. 47.

When an order calls for specific tests by the research department, a copy is made out and sent to the research department for their guidance. This is an extra copy and is inserted in a set of tickets only when needed (Fig. 48).

**SHEET RESEARCH MEMO**

ENTIRE TOTAL
TOTAL ENT.
CUST. ORD. NO DATED
CU.
TER.
ENTERED
< >
PLANT
SHIP

BARS
LBS. PCS FT.
PROD.
WIDTH
TOL.
SIZE
GA.
ALLOY
TEMPER
LENGTH

BILL TO
SHIP TO
ACCT. OF
VIA.
B/L

FIG. 48.

Figure 49 shows the copy sent to the shipping room. When the mill order arrives in the shipping room with the metal, the tickets are matched, the weights noted on the shipping order, and the date of shipment is stamped on the shipping order and sent to the billing department for billing.

**SHEET SHIPPING ORDER**

ENTIRE TOTAL  CU.  < >  B 2700
TOTAL ENT.  TER.  PLANT
CUST. ORD. NO.  DATED  ENTERED  SHIP

BARS  SIZE  ALLOY
LBS.  PCS.  FT.  WIDTH  GA.  TEMPER
PROD.  TOL.  LENGTH

BILL TO
SHIP TO
ACCT. OF  B/L
VIA

| Kind of Package | | WR. | SCL | PCK | MARK | CHK | ON PROD. | TOTALS | PRICE | AMT. INVOICE |
|---|---|---|---|---|---|---|---|---|---|---|
| Package No. | | | | | | | | | | |
| Pieces-Feet | | | | | | | | | | |
| Total Gross | | | | | | | | | | |
| Lot Weight | | | | | | | | | | |
| Net | | | | | | | | | | |
| Tare | | | | | | | | | | |
| Gross Package | | | | | | | | | | |

FIG. 49.

As the name implies, Fig. 50 shows an extra memo. During a period of war production this copy may be filled out and sent to the company's priorities department so that it can tabulate and check on the amount of war material entered in the mill.

**SHEET EXTRA MEMO**

ENTIRE TOTAL  CU.  < >  B 2700
TOTAL ENT.  TER.  PLANT
CUST. ORD. NO.  DATED  ENTERED  SHIP

BARS  SIZE  ALLOY
LBS.  PCS.  FT.  WIDTH  GA.  TEMPER
PROD.  TOL.  LENGTH

BILL TO
SHIP TO
ACCT. OF  B/L
VIA

FIG. 50.

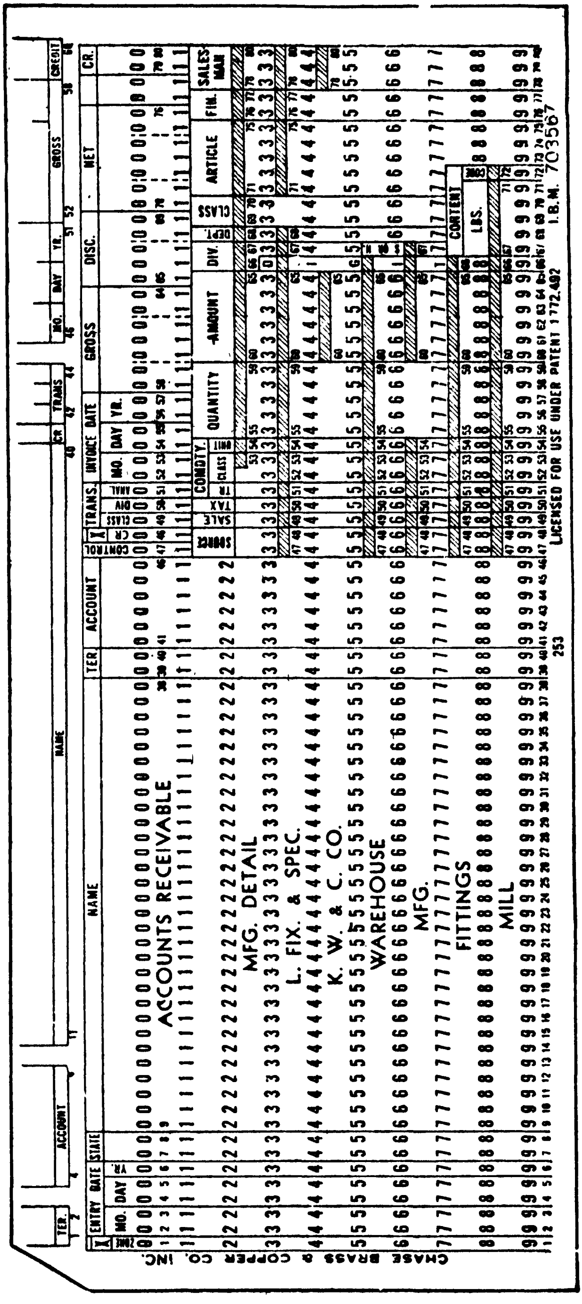

CHASE BRASS & COPPER CO. INC.
ACCOUNTS RECEIVABLE
MFG. DETAIL
L. FIX. & SPEC.
K. W. & C. CO.
WAREHOUSE
MFG.
FITTINGS
MILL
LICENSED FOR USE UNDER PATENT 1 772 492
I.B.M. 703567

FIG. 51.

The type of ticket used by the record department on the I.B.M. tabulating machines is shown in Fig. 51. It will be noted that this is also used by the accounting department and various divisions of the company. For instance, L. Fix & Spec. means lighting fixtures and specialty sales; K. W. & C. Co. means Kennecott Wire & Cable Co.; MFG. means Waterbury Manufacturing Co.; there are also the fittings and mill divisions.

The sheet in Fig. 52 shows the amounts of various gauges of sheet that can be scheduled weekly (amounts fictitious). As sheet orders are received, they are applied against the different classifications until the full amount has been scheduled, and then the scheduler starts in with the next week. The column headed "Number of promises made" is used to guide the scheduler on the number of promises being

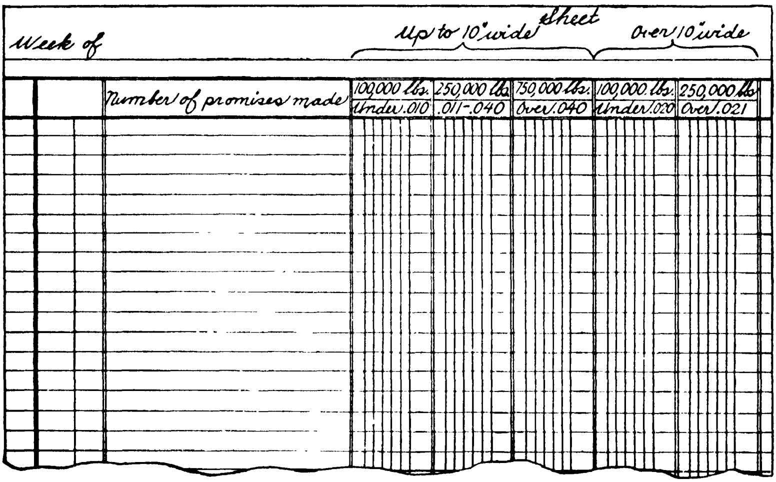



FIG. 52.

made weekly, since it has been found from past experience that the mill can follow up and keep only a limited number of promises. For instance, let it be assumed that 500 is the maximum number of promises that can be kept, with a total poundage of 1,500,000 pounds (an average of 3,000 pounds per lot). If business should fall off and smaller individual orders amounting to 750,000 pounds are received averaging about 750 pounds per lot, it would not necessarily mean that 1,000 promises could be kept. One of the principal reasons of course is the extra setups involved on smaller lots (3,000 pounds being an economical mill lot). Also the follow-up staff necessary for normal operations would not be adequate for handling the increased number of orders.

There is no printed form for this schedule, since it varies from time to time, depending on the class of work being received. For instance, at the present time a great deal of cartridge metal is going through the mill that can be produced in large quantities. In normal times, there would perhaps be a large amount of radiator brass or copper going through the mill that is finished on very thin gauges requiring more rolling operations, thus cutting down poundage. Naturally, a higher price is obtained to compensate for these additional operations.

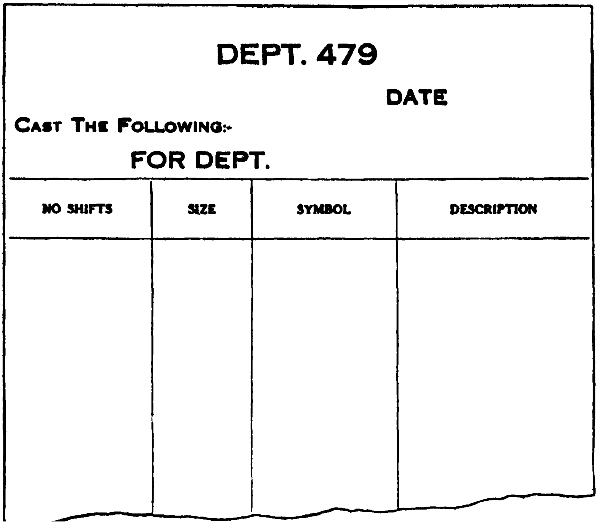
| ORDERS | ROD | WIRE | COPPER SHEET BRASS SHEET | WAT. TUBE PIPE | SS. TUBE | TOTAL TUBING | ORDERS RECEIVED TOTAL | AT MARKET | CONT. SPEC. |
|---|---|---|---|---|---|---|---|---|---|
| Today | | | | | | | | | |
| This Mo. | | | | | | | | | |
| Av. This Mo. | | | | | | | | | |
| Av. Last Mo. | | | | | | | | | |
| Av. | | | | | | | | | |
| Total This Yr. To Date | | | | | | | | | |
| Total Last Yr. To Date | | | | | | | | | |
| Unf. Ord. | | | | | | | | | |

| SHIPMENTS | | | | | | | |
|---|---|---|---|---|---|---|---|
| Today | | | | | | | |
| This Mo. | | | | | | | |
| Av. This Mo. | | | | | | | |
| Av. Last Mo. | | | | | | | |
| Av. | | | | | | | |
| Total This Yr To Date | | | | | | | |
| Total Last Yr To Date | | | | | | | |

| UNFILLED ORDERS | |
|---|---|
| Specified | |
| Unspecified Contracts | |
| Total | |

Fig. 53.

The report (Fig. 53) furnished daily by the record department shows the amount of orders received and also the shipments. This shows at a glance the amount of unfilled orders in the mill under each division, the average for this and last month, and comparisons between this year and last.


DEPT. 479

DATE

CAST THE FOLLOWING:-

FOR DEPT.

| NO SHIFTS | SIZE | SYMBOL | DESCRIPTION |
|---|---|---|---|
| | | | |

FIG. 54.

If semifinished stores are exhausted, the sheet-mill foreman fills out a sheet (Fig. 54) requesting castings for the various orders he cannot start because of lack of metal.

When the casting foreman receives requests for various castings from the different mill departments—such as the sheet mill, rod mill, tube mill, or wire mill, he makes up a schedule (Fig. 55). This shows the number of pots (furnace charges), the size of molds (width or diameter, as the case may be), the kind of material (mixture symbol), and the fire number. He also inserts the name of the caster he assigns to the various fires.

# CASTERS DAILY SCHEDULE

DATE______ DATE______

| THIRD SHIFT | | | | | FIRST SHIFT | | | | | SECOND SHIFT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| POTS CAST | CASTER | SIZE MOULDS | KIND OF METAL | FIRE No. | POTS CAST | CASTER | SIZE MOULDS | KIND OF METAL | FIRE No. | POTS CAST | CASTER | SIZE MOULDS | KIND OF METAL | FIRE No. |
| | | | | | | | | | | | | | | |
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FIG. 55.

**FLAT METAL CAST IN DEPT. DATE**

| BARS | C. O. No. | SIZE | KIND | CASTER | FIRE |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
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SIGNED____________________DEPT.

FIG. 56.

After the material is cast, the casting-shop office sends a report to the mill involved, showing the actual amount cast on each size requested (Fig. 56).

**REPORT OF SHEET STOCK**

| GAGE | WIDTH | ALLOY | AUTH | 478 | 211 | 204 | TOTAL |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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FIG. 57.

After the material is cast, some of it is retained in its original size, and some is run down to semifinished sizes. The sheet-stores department furnishes the sheet mill with an up-to-date inventory every morning (Fig. 57).

WATERBURY MILL OPERATIONS

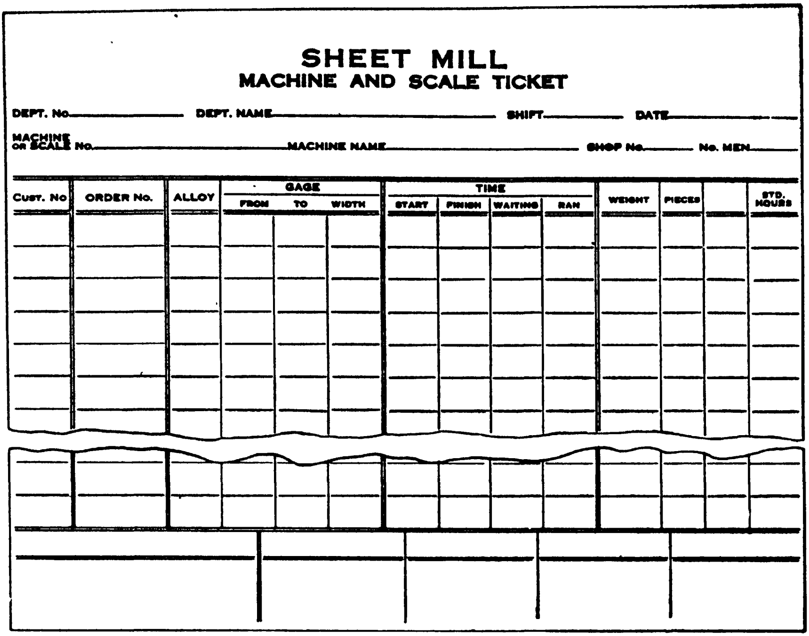
WEEK ENDED

| | ROD | WIRE | C M W SHEET | TUBE | C R M SHEET | TOTAL |
|---|---|---|---|---|---|---|
| Metal in Works A. M. | | | | | | |
| Used in Casting | | | | | | |
| From Outside Sources | | | | | | |
| Toll Additions | | | | | | |
| Misc. Receipts | | | | | | |
| Dept Transfers – In | | | | | | |
| TOTAL ADDITIONS | | | | | | |
| Shipments to Customers and Warehouses | | | | | | |
| Shipments to Cleveland Mill | | | | | | |
| Mill and Casting Scrap and Losses | | | | | | |
| Toll Deductions | | | | | | |
| Misc. Deductions | | | | | | |
| Dept. Transfers—Out | | | | | | |
| TOTAL DEDUCTIONS | | | | | | |
| Metal in Works P M. | | | | | | |
| | | | | | | |
| Process—Billets & Stock | | | | | | |
| Process—Other Metal | | | | | | |
| PROCESS TOTAL | | | | | | |
| Finished Stock—Depts. 486 and 207 | | | | | | |
| Finished Stock—Dept. 801 | | | | | | |
| Finished Stock—Houston & Pt. Arthur | | | | | | |
| Finished—Shipping Depts. | | | | | | |
| FINISHED TOTAL | | | | | | |
| | | | | | | |
| Production—This Week Days | | | | | | |
| Production—Daily Av This Week | | | | | | |
| Production—Daily Av. Last 4 Weeks | | | | | | |
| Production per Man Hour This Week | | | | | | |
| Production per Man Hour Last 4 Weeks | | | | | | |
| Mill Scrap—lbs This Week | | | | | | |
| Mill Scrap—Percentage This Week | | | | | | |
| Mill Scrap—Percentage Last 4 Weeks | | | | | | |

RECORD DEPT.

FIG. 58.

A report furnished weekly by the record department shows the amount of material in the works and other various information as listed (Fig. 58). It shows the amount of material in process, the finished stocks in different departments, and the production for the preceding week. The latter is of special importance.



SHEET MILL
MACHINE AND SCALE TICKET

DEPT. No.______ DEPT. NAME______ SHIFT______ DATE______

MACHINE OR SCALE No.______ MACHINE NAME______ SHOP No.______ No. MEN______

| CUST. No | ORDER No. | ALLOY | GAGE | | | TIME | | | | WEIGHT | PIECES | | STD. HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | FROM | TO | WIDTH | START | FINISH | WAITING | RAN | | | | |

Fig. 59.

The sheet shown in Fig. 59 is retained at the various machines in the sheet mill for notations regarding the progress of orders. It will be noted that the account number, the mill order number, the alloy (mixture symbol), and the gauge from which it was rolled to weight, pieces, etc., are shown. When the material is finished, it automatically goes through the sheet-mill inspection department. After inspection this same sheet is used by the weigher, and the actual amount and number of pieces, etc., that have been passed by the inspectors and sent to the shipping room are recorded thereon.

Date____________

________________Mill

**FOLLOW-UP REPORT**

All items shown below require immediate attention. Please check each item and return this sheet, duly signed, at once to our Follow-Up Dept., noting any item requiring a repromise date.

| M. O. | Dia. No. | Pounds | Alloy | Size and Length | Last Oper and date | Date Sched | Will be Kept | Reprom Date |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
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Mill Foreman________________

FIG. 60.

When orders are lagging, the production-department follow-up clerks make out lists showing the mill-order number, the account number, the alloy, and the size. They also fill in the last operation and date so that the material can be easily found in the mill (Fig. 60). The last three columns show the date scheduled and a column to be checked if promise is to be kept and, if not, a column to show a repromise date.

# APPENDIX C

# A TYPICAL JOB-ORDER PRODUCTION-CONTROL SYSTEM

A smoothly operating, automatic, efficient system of production planning and control is a very real and important asset to any manufacturing concern. With every increase in plant size, the need for such a system increases in geometric progression, for the number of job units handled becomes greater and the problem of their disposition more complex. In addition, the problem becomes even more acute if the number of different items in proportion to the total number of items is high. Here the problem of routing, scheduling, and merely keeping track of each different item during manufacture becomes of prime concern to management. Because it is always interesting to examine what others have done, an actual production-control system will be examined to see how it works. The system described is that used in 1942 by the Farrel-Birmingham Company of Ansonia, Conn., a moderately large job-order factory specializing in the manufacture of various kinds of heavy machinery such as rolling mills, presses, roll grinders, marine reduction-gearing, and rubber-processing machinery. Nearly every order is different from all others previously manufactured, and here is found the problem of production control in its most complex form.

In order to understand better how the production-control system of the Farrel-Birmingham plant operates under actual working conditions, it will perhaps be useful to follow an actual order through the various production divisions of this factory and to note, as the order progresses toward its completion, just how it is handled by a planning and control system. Through examination of an actual case we can begin to appreciate the problem that management faces in assuring itself that each order will be finished as nearly as possible on the schedule that has been set for it and that the purchaser has been informed to expect. The system must also serve as a check against loss of an article during the process of production, among thousands of other different parts in various stages of manufacture or assembly.

Figure 61 is the reproduction of an actual order picked at random from the thousands that are manufactured each year. This order involves work in most departments and is representative of the type of heavy machine work that is customarily done, except that for purposes of clarity a comparatively small order was selected. After receipt of an order by the sales department, it is sent to the order department, where it is transcribed on a special shop form for convenient shop use. Naturally, larger orders involving more items will have more sheets, and in the case of a large machine with perhaps 3,000 or more parts, blueprinted parts-list sheets will be made up by the engineering department and written by the order department. Sometimes the number of list sheets will run as high as 50 or more, but these sheets are only the continuation of an original sheet similar to the one for shop order Y-1509 (Fig. 61), which is being built for the South Porto Rico Sugar

Company Trading Corporation. Examination of Fig. 61 reveals that this order is for some change-over parts for a sugar mill that has been previously constructed, and on this sheet the four items necessary for this change are clearly described.

| | | |
|---|---|---|
| 5/8 \| Deliver to 52 \| Charge to 52 | Date of order 5/16/40 | Production order No. Y-1509 |
| Customer<br>So. Porto Rico Sugar Co.<br>Trading Corp. for Santa Fe Mill | Due dates<br>To be completed by<br>14 6/5<br>22 6/10<br>20 6/25<br>M 7/17 | Sheet No. 1<br><br>Sheets |
| Machine No. General drawing | | |
| Description<br>16″ side-roll box—crown wheels and couplings for 32″ × 66″ mill<br>This list is for one, make One on this order | Date of required shipment<br>7/22 | Ship with |

| Item | Ordered from dept. | Make | Mat. | Patt. | Drawing | List of parts |
|---|---|---|---|---|---|---|
| 1 | OP | 2 | 35M | RF-14/128 | 192-485 | Side-roll boxes |
| 2 | | | | | | |
| 3 | 12 | 16 | MI | | 192-485 | 1″ pipe plugs for item 1. |
| 4 | | | | | | |
| 5 | | | Boxe | s machined | ready fo | r 16″ journal liners (no liners furnished) |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | OP | 3 | 45C | 2926 | 193-22 | 32 1/2″ crown wheels—18 T.—5.672″ |
| 9 | | | | | | P.—14 1/2″ face—bore 17.508″ |
| 10 | | | | | | Two straight featherways 2 3/8″ × |
| 11 | | | | | | 3/4″ at 90° |
| 12 | | | | | | |
| 13 | OP | 2 | 25C | RF-5/30 | 192-14 | Couplings—12 11/16″ square for 12 1/2″ |
| 14 | | | | | | square shaft |
| 15 | | | | | | |
| 16 | | Pack | for e | xport | | |
| 17 | | | | | | |
| 18 | | | Note: | The above | boxes ar | e for changing over the roll journals |
| 19 | | | fro | m 15″ and | 14″ dia. t | o 16″ per layout PS-966 and replace old |
| 20 | | | box | es on 192-1 | 09 for ho | using 192-108. Rolls in future are to be |
| 21 | | | fur | nished to 2 | 01-350. | |
| 22 | | | The | first shafts | are on or | der W-4372. |
| 23 | | | The | first change | -over ste | p made on order W-4373. |
| 24 | | | | | | |
| 25 | | | | | | |
| 26 | | | | | | |
| 27 | | | | | | |
| 28 | | | | | | |
| 29 | | | | | | |
| 30 | | | | | | |
| 31 | | | | | | |

Fig. 61.

Reference is given to the pattern number, the drawing number, and the kind of material from which the parts are to be constructed: 35M represents a grade of Meehanite; 45C and 25C are 45 and 25 carbon steel. The date this order was signed by the customer (5/16/40) appears at the top of the form, and at the upper

left we see that the order actually went into production on June 5. The reason for three weeks' delay is that engineering work had to be done before actual manufacture could begin. Already we can see the influence of the scheduling timetable, for order Y-1509 was due to be out of department 14 (the engineering department) by June 5, and thus far the schedule has been exactly adhered to. These schedule dates were set the first few days after the order was received, and it was decided that this order should be through department 22 (the pattern shop) on the tenth, the foundry (department 20) on the twenty-fifth, and through the machine department by July 17. Shipment has been promised the customer by the twenty-second of July.

On June 5 the order department received the data necessary to write the order, and copies were sent to all affected departments. The copies that we are interested in at present are the two copies that are sent to the foundry control office. Upon receipt, they are carefully looked over for all work in either the pattern shop or the foundry, as in items 1-1, 1-8, and 1-13.[1] Item 1-3 is a stock item and has been

6/6

Iron

Steel ✓

So. Porto Rico Sugar Co. Trading Corp

Order No. Y-1509

Pattern Due Date 6/10

Foundry Due Date 6/25

| Item No. | Pattern No. | No. Castg. | Name of Piece | Mat. | Pattern to Foundry | No. & Date Cast | Shipped from Foundry | Remarks |
|---|---|---|---|---|---|---|---|---|
| 108 | 2926 | 3 | Crownwheel | 45C | | | | OP. |
| 113 | RF-1/30 | 2 | Coupling | 25C | | | | OP. |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Fig. 62.

ordered from department 12, which is the stock room. The clerk keeping the foundry control records will enter pertinent information on a pattern-shop and foundry control record form, and at the completion of his original entries the iron-casting sheet for order Y-1509 will appear as in Fig. 62, and the sheet will be filed according to shop-order number in the foundry control book. The steel casting will be entered on a steel-casting sheet. One of the two order sheets received from the order department will then be sent to the foundry and the other to the pattern shop.

The order sheet that goes to the foundry time office will be filed according to shop-order number in loose-leaf binders provided for that purpose and will serve as a source of reference for the foundry foremen and the supervisory force.

The sheet that is sent to the pattern shop will be looked over by the pattern-shop clerk for work in that shop and the three items on order Y-1509 noted. From here on, for the purpose of reducing the bulk of this examination, we shall follow the production only of item 1-8, the three crown wheels. The production of the other two items is similar, and in actual practice the production of each item is carried on independently of other related items.

[1] The first number of the total item number stands for the sheet number on the order, and the second for the item number on the left side of the sheet.

The clerk then notes that pattern 2926 called for on item 1-8 is an old pattern (OP) and will notify the pattern storehouse that pattern 2926 is needed. The clerk will then take the index card for pattern 2926 from his files. This card is shown in Fig. 63. After marking the order number in the left-hand column, he will note on this card how the pattern will be rigged for this job and other pattern-shop information. If the order sheet had called for a new pattern (NP), the clerk would have taken a blank index card and filled it out in a similar manner. This index card is then placed in the work-in-process file, although this pattern actually requires no pattern-shop work. The order sheet is placed in the pattern-shop loose-leaf binder of active pattern-shop orders.

In the meantime, another copy of the order sheet for order Y-1509 has been sent to the routing and scheduling department, which is responsible for printing and

2926

MACHINE Sugar Mill Crownwheel 32.50"-18-5.672" 16" Face

| ORD. No. | DRG. No. | CHANGE No. | CHANGES | MAN | TIME | LUMBER | SHIPPED | DATE | CASTINGS |
|---|---|---|---|---|---|---|---|---|---|
| L 8471 | 193-22 | 16½ | New | Eickson | 57½ | | Birdsboro Fdy | 7/31/29 | 10 |
| W-7041 | 193-22 | 16½ | B 16" Face 1CB 1LP 450 | Hazard | 6 | | F-13 Co | 7/17/39 | 2 |
| Y-1509 | " | 17½ | B 14½ " " " " | " | | | " | 4/11/40 | 3 |

LOOSE PIECES / CORE BOXES / PRINTS MATERIAL 200

REMARKS

36.24" P. Dia

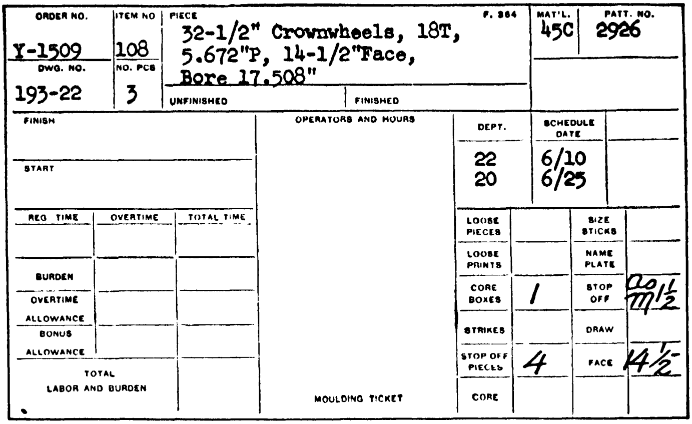
CHECKED BY

FIG. 63.

issuing the casting tickets for authorization of the actual work in the foundry. These cards are first sent to the pattern shop. The clerk will place all tickets for new patterns and old pattern changes on the pattern-shop foreman's desk for the foreman's attention. The foreman then distributes these casting tickets to the patternmakers. They note upon the molding ticket (Fig. 64), the number of loose pieces, loose prints, core boxes, and other information concerning the pattern and its use for this job. The cleaning ticket (Fig. 65) has no entries made on its face by the pattern shop, since it is for the use of the cleaning room for production-control and time-keeping purposes. After the new patterns have been made or the changes have been made upon old patterns, an inspector will check over the work for adherence to the blueprint and will signify approval of the work by returning the casting tickets to the pattern-shop clerk.

Order Y-1509 had no pattern-shop work, and the casting tickets were marked by the pattern-shop clerk. The two tickets as they now appear are shown in Figs. 64 and 65, and the work is ready for the foundry. These tickets are printed on yellow-colored cards, used to denote to the foundry that a steel casting is called for.

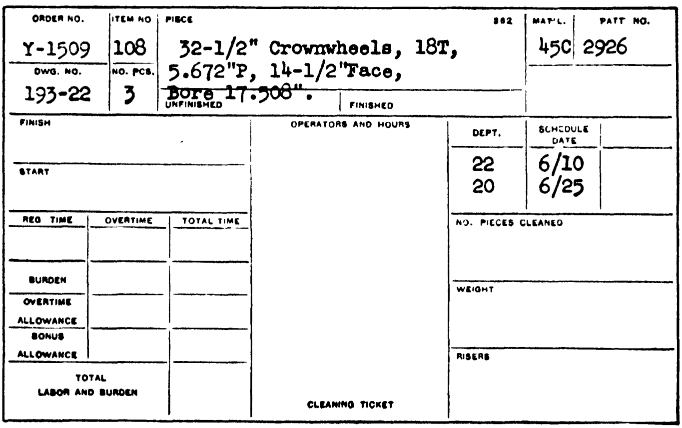
If the castings for these crown wheels had been 50 Meehanite, the same information would have appeared on pink-colored tickets; 25 or 35 Meehanite would be indicated by salmon-colored tickets. These three colors are rigidly adhered to for all regular



ORDER NO. Y-1509 | ITEM NO 108 | PIECE 32-1/2" Crownwheels, 18T, 5.672"P, 14-1/2"Face, Bore 17.508" | F. 364 | MAT'L. 45C | PATT. NO. 2926
DWG. NO. 193-22 | NO. PCS 3 | UNFINISHED | FINISHED
FINISH | START | OPERATORS AND HOURS | DEPT. 22, 20 | SCHEDULE DATE 6/10, 6/25
REG TIME | OVERTIME | TOTAL TIME
BURDEN | OVERTIME ALLOWANCE | BONUS ALLOWANCE | TOTAL LABOR AND BURDEN
LOOSE PIECES | SIZE STICKS
LOOSE PRINTS | NAME PLATE
CORE BOXES 1 | STOP OFF 20 1/2, 11 1/2
STRIKES | DRAW
STOP OFF PIECES 4 | FACE 14 1/2
CORE
MOULDING TICKET

Fig. 64.

jobs. If, however, a casting were scrapped, the new card for the replacement would be colored green and would carry a special replace number under the regular shop number. The green color helps to call attention to the more urgent nature of this job and serves to expedite its manufacture. Breakdown jobs that have preference



ORDER NO. Y-1509 | ITEM NO 108 | PIECE 32-1/2" Crownwheels, 18T, 5.672"P, 14-1/2"Face, Bore 17.508". | 362 | MAT'L. 45C | PATT NO. 2926
DWG. NO. 193-22 | NO. PCS. 3 | UNFINISHED | FINISHED
FINISH | START | OPERATORS AND HOURS | DEPT. 22, 20 | SCHEDULE DATE 6/10, 6/25
REG TIME | OVERTIME | TOTAL TIME
BURDEN | OVERTIME ALLOWANCE | BONUS ALLOWANCE | TOTAL LABOR AND BURDEN
NO. PIECES CLEANED
WEIGHT
RISERS
CLEANING TICKET

Fig. 65.

over all other types of jobs are printed on white cards with a bright red band down both sides and are easily distinguishable by their color from all other jobs.

The pattern-shop clerk will then make out a yellow coremaking ticket for each core box. The coremaking ticket for item 1-8 of order Y-1509 appears in Fig. 66. Coremaking tickets are similarly written for all jobs, whether for new patterns, pattern changes, or old patterns; and yellow, pink, salmon, green, white with red stripes, and plain white are used to correspond to the casting tickets as described.

In the case of new patterns or old pattern changes, the clerk will take the tickets to where the pattern lies in the pattern shop and tack them securely to the pattern. If the pattern is an old one, the clerk will send the molding, cleaning, and coremaking

| ORDER NO. | ITEM NO. | PIECE | MAT'L. | PATT. NO. |
|---|---|---|---|---|
| Y-1509 | 108 | 32½" Crownwheels | 45C | 2926 |
| DWG. NO. | NO. PCS. | UNFINISHED / FINISHED | | |
| 193-22 | 3 | | | |

| FINISH | | | OPERATORS AND HOURS | DEPT. | SCHEDULE DATE |
|---|---|---|---|---|---|
| START | | | | 22 | 6/10 |
| | | | | 20 | 6/25 |
| REG. TIME | OVERTIME | TOTAL TIME | | NO. OF CORES TO MAKE | 3 W.C. as m. |
| | | | | CORE BOX NUMBER | 1 |
| BURDEN | | | | NUMBER OF CORE BOXES | 1 |
| OVERTIME ALLOWANCE | | | | CORES PER SET | 1 W.C as m. |
| BONUS ALLOWANCE | | | | | |
| TOTAL LABOR AND BURDEN | | | COREMAKING TICKET | | |

FIG. 66.

tickets to the pattern storehouse, and the storekeepers will attach the tickets themselves. In either case, the pattern-shop clerk will notify the traffic department wher the pattern is ready for delivery to the foundry, and a truck will move the pattern.

PATTERNS DELIVERED

DELIVERED FROM DEPT. 22 TO DEPT. 20 DATE June 11-1940

| ORDER NO | PATT. NO. | NAME OF PATTERN | LOOSE PIECES | LOOSE PRINTS | CORE BOXES | STRIKES | STOP OFF PIECES | SIZE STICKS |
|---|---|---|---|---|---|---|---|---|
| Y-1509 | RF 14/128 | Side Boxes 1-1 6/10 | 1 | | 4 | | | |
| Y-1509 | 2926 | Crownwheels 1-8 6/10 | | | 1 | | 4 | |
| Y-1509 | RF 1/30 | Couplings 1-3 6/10 | 2 | | | | | |

FIG. 67.

The index card is taken from the work-in-process file, and the date of shipment from the pattern shop and the foundry it was shipped to (in this case, Farrel's own foundry) are entered upon the card. It is then returned to the file cabinet where all index cards are kept that are not active in the pattern shop. The shop-order sheet is at

this time removed from the active book and filed away for reference. The shipment is noted on the pattern-delivery form. At the end of each day one copy is sent to the foundry to serve as a notification of work ready for molding. Another copy is sent to the foundry control office, which makes a note of the date of delivery of the pattern to the foundry. This copy is in turn sent on to the machine-shop control office, which will be considered later. A copy of a pattern-delivery sheet appears in Fig. 67, with the delivery of patterns for order Y-1509 noted. It can be seen that item 1-8, which we are following, is now one day late on its schedule, which is unusual for an old pattern that must be delivered only from the storehouse. Possibly a delay in receipt of casting tickets was the cause.

No system of standards is maintained in the pattern shop, for it is believed that the work is of such a varied nature that a fair set of standards would be difficult to

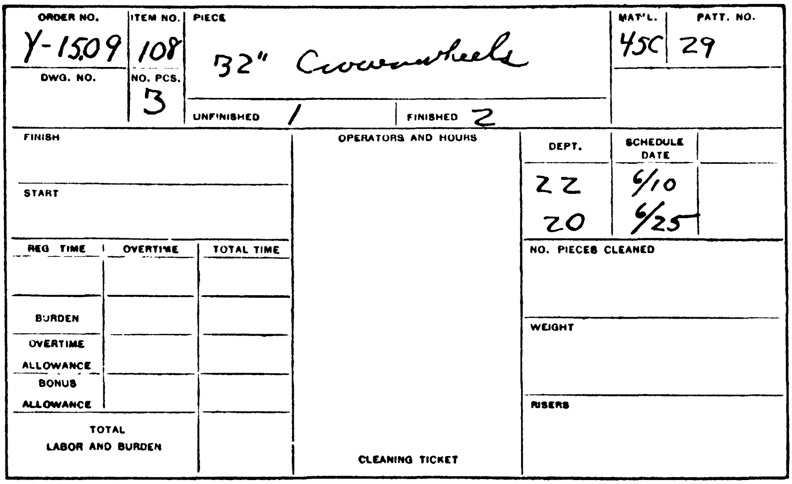

ORDER NO. Y-1509
ITEM NO. 108
PIECE 32" Crownwheels
MAT'L. 45C
PATT. NO. 29
DWG. NO.
NO. PCS. 3
UNFINISHED 1
FINISHED 2
FINISH
START
OPERATORS AND HOURS
DEPT. 22 20
SCHEDULE DATE 6/10 6/25
REG TIME
OVERTIME
TOTAL TIME
BURDEN
OVERTIME ALLOWANCE
BONUS ALLOWANCE
TOTAL LABOR AND BURDEN
CLEANING TICKET
NO. PIECES CLEANED
WEIGHT
RISERS

FIG. 68.

devise. It must be remembered that, by contrast with the foundry and machine shop, few jobs are ever repeated here, for patterns are kept year after year and are used on the many different jobs that involve the same part. Then, too, the various operations in making a pattern are not performed by different operators, and one patternmaker normally carries a particular pattern through to completion. The foundry control office watches the progress of the various jobs and will notify the pattern shop if a pattern fails to be delivered on the scheduled date. The index cards in the work-in-process file also serve as a reminder to the pattern-shop clerk of what jobs are in progress, and the casting tickets that the foremen or a patternmaker have for a particular job have the scheduled delivery date to the foundry upon them. In general, the number of job units in production in the pattern shop is very much smaller than in either the foundry or the machine shop, and personal supervision by the foremen is sufficient to ensure that the work is completed as nearly as possible on time.

On arrival of the patterns at the foundry, the pattern is checked off against the pattern delivery sheet, and work is distributed to the steel, iron, or roll floors according to plan. When work is started on the molding of a casting, casting tickets are de-

tached from the pattern, and the cleaning ticket goes to the foundry time office to serve as a record of work in process. Here it is placed in a visible-type wall rack. The molding and coremaking tickets are distributed to operators as authorization of work. The time at the start and finish of the job is stamped by a time clock in the proper spaces on the face of the tickets. If the job is interrupted, the operator will return the ticket to the time office with the supplementary time data stamped on the back of the card. When any operator is finished with a particular job, even if the job itself may not be completed, the timekeeper will enter the operator's name and hours worked in the center of the work card before giving the card to another operator. On completion of the job, the total time is entered in the spaces provided on the lower left-hand corner of the work card. The actual pouring of the metal is scheduled entirely by the foreman of the particular foundry floor in question.

| ORDER NO | ITEM NO. | PIECE 412-A | MAT'L | PATT. NO. | |
|---|---|---|---|---|---|
| Y-1509 | 108 | 32-1/2" Crownwheels 18T 5.672"P 14-1/2" Face | 45C | 2926 | |
| **DWG. NO.** | **NO PCS** | **CUSTOMER** | **CLASS** | **PATT. DEL'Y** | |
| 193-22 | 3 | Bore 17.508" | | | |

| CAST | CHG'D | NO PCS | | | | HOURS | WEIGHT | COST | LB. COST |
|---|---|---|---|---|---|---|---|---|---|
| | | | MELTED IRON | @ | LB. | | 6650 | | |
| 6/19 | 6/28 | 3 | WEIGHT EXPENSE | @ | LB. | | | | |
| | | | CLASS RISK COVERAGE | @ | LB. | | | | |
| | | | | | | | | | |
| | | | 632 | | | $4^{5}$ | | | |
| | | | MOULDING EXPENSE 648 | @ | HR | $8^{2}$ | | | |
| | | | APPRENTICE MOULDING 695 | @ | HR. | $7^{0}$ | | | |
| | | | DIRECT HELPER 675 & 681 | @ | HR. | $11^{2}$ | | | |
| | | | | | | | | | |
| | | | COREMAKING EXPENSE 579-591 | @ | HR. | $9^{2}$ | | | |
| | | | APPRENTICE COREMAKING | @ | HR. | $^{6}$ | | | |
| | | | | | | | | | |
| | | | CLEANING EXPENSE | @ | HR | $50^{4}$ + $1^{2}$ | | | |
| | | | GRINDING EXPENSE | @ | HR. | $3^{6}$ | | | |
| | | | CUTTING RISERS | @ | LB | | | | |
| | | | | | | | | | |
| | | | ANNEALING EXPENSE | @ | LB. | | | | |
| | | | | | | | | | |
| | | | RISER WEIGHT | @ | LB | | | | |
| | | | FOUNDRY COST | | | | 6650 | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | TOTAL COST | | | | | | |

FIG. 69.

When the casting is cool enough to handle, the cleaning ticket, which was retained in the foundry time office, is sent to the cleaning room as an indication that a casting is ready to be worked upon. If a cleaning ticket is sent to the cleaning room similar to the ticket in Fig. 68, the foreman will know that only part of the job has been cast and that only two of the castings of item 1-8 on job Y-1509 are ready for cleaning. He will retain that pencil-written cleaning ticket until the arrival of the regular printed cleaning ticket that is shown in Fig. 65, signifying the completion of the job. While the job is in the cleaning room, the cleaning tickets are kept in a visible wall rack such as was used in the foundry time office. A record of operators and their time is entered on these cards. When the cleaning is completed the tickets are sent to the foundry cost office.

In the foundry cost office the molding, coremaking, and cleaning tickets are gathered together, and the information is compiled and entered on foundry cost cards printed from the same ditto stencil used to print the molding and cleaning cards. Figure 69 shows the cost card for item 1-8 on order Y-1509 with the time entries complete. Later the cost of the job will be figured for the job and also entered on

this same card. The cost office is the final disposition of our foundry control cards. It performs a function apart from the production scheduling and control department.

REPORT OF CASTINGS MADE 6/19/40

| ORDER NO. | NO. CASTINGS | PATTERN NO. | ORDER NO. | NO. CASTINGS | PATTERN NO. |
|---|---|---|---|---|---|
| TB-6442 | 1 | C3-1309 | | | |
| Y-1833 | 2-304 | DN-258 | | | |
| | | | | | |
| | | | | | |
| Y-1509 | 2-101 | RF - 14/128 | | | |
| " | 3-108 | 2926 | | | |
| " | 2-113 | RF - 1/30 | | | |

Fig. 70.

Each day the foremen in the foundry make out a report of the castings they have made. One copy is sent to the foundry control office, where each item is posted to

INTER-DEPARTMENT SHIPPING

SHEET No. 398 DATE 6/24/40

SHIPPED TO Dept 40

SHIPPED VIA Our truck

| ORDER NO. | ITEM NO. | PCS. | DESCRIPTION | | | FROM DEPT. | TO DEPT. |
|---|---|---|---|---|---|---|---|
| W-8079 | 107 | 1 | Pinion | 2671 | 6/13 | 22 | 2 |
| W-7658 | 1904 | 1 | Collar | 12058 | 9/27 (4) | 12 | 8 |
| Y-511 | 217 | 2 | Side plates (4) | 1455813 | 6/2 | 102 | 9 |
| | | | | | | | |
| Y-1254 | 1728 | 2 | Stands | XZ-423 | 6/22 | | |
| Y-1509 | 101 | 2 | Boxes | RF 14/128 | 6/25 | | |
| " | 108 | 3 | Crownshells | 2926 | | | |
| " | 113 | 2 | Couplings | RF-1/30 | | | |

Fig. 71.

the proper sheet in the foundry control book (Fig 62). Another copy goes to the machine-shop control office and a third to the foundry cost office. Figure 70 is a

reproduction of this report on June 19, and on it we find the three castings for order Y-1509. In a similar manner, when the cleaning room has finished the cleaning of these castings and has sent them to the machine shop, a record of that shipment is sent to the foundry control office and to the machine-shop control office. Figures 72

TRAFFIC DEPT

MATERIAL RECEIVED____________________FOR USE ON ORDER NUMBERS AS FOLLOWS

| SHOP ORDER NO | DELIVERED TO DEPT | FOR DEPT | DESCRIPTION |
| --- | --- | --- | --- |
| | | | |

FIG. 72.

and 73 show the interdepartment shipping memorandum that records the transfer of items 1-8 on Y-1509 to the machine department.

At this point the work of the foundry control office is complete, and we can see

**MEMORANDUM**

TRAFFIC DEPT.

Mr.____________________ Date________________

We have this day received the following

from________________________________________

which has been delivered to Dept____________

Copy to Billing Dept.:

The____________charges on the above are____________

FIG. 73.

the completed record of item 1-8. It is reproduced in Fig. 74. We note that the pattern was shipped to the foundry on June 11 (one day late), that the molding and casting were done promptly, and that the three castings were shipped from the

foundry on June 24, which was one day ahead of schedule. When the other items are completed, this sheet will be taken out of the foundry control book and destroyed, for the foundry control office has fulfilled its purpose.

While these crown wheels have been in production in the pattern shop and foundry, the routing department has been looking over the order and the blueprint of drawing 193-22 and planning how the necessary work can best be done on item 1-8. Eventually notes concerning the scheduling, routing, and standard time allowed for each operation are penciled on the margin of their copy of the shop-order sheet, which is slightly bigger and of heavier paper stock than those sent to other departments. The complete scheduling for order Y-1509 is shown in Fig. 75. At the right of item 1-8 we see that the pattern and foundry dates have been copied off the order and that the first machine-shop operation is to be vertical boring and turning of machine 4751, that the operation should take place before July 8, and that the

6/6

So Porto Rico Sugar & Trading Corp

Iron

Steel ✓

Order No. Y-1509

Pattern Due Date 6/10

Foundry Due Date 6/25

| Item No. | Pattern No. | No. Castg. | Name of Piece | Mat. | Pattern to Foundry | No. & Date Cast | Shipped from Foundry | Remarks |
|---|---|---|---|---|---|---|---|---|
| 108 | 2926 | 3 | Crownwheel | 45C | 6/11 | 3 6/19 | 6/24 | OP ✓ |
| 113 | RF 1/30 | 2 | Coupling | 25C | 6/11 | 1 6/17 - 1 6/20 | 1 6/22 - 1 6/24 | OP ✓ |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

FIG. 74.

operation should take 22.5 hours to perform. The asterisk after the time denotes that this is a *standard time* for this operation, which has been performed in the past upon similar work. This is important, because the operator is paid a bonus on his work if it is performed in less than the standard time. If the operation is a new one, an *E* (estimated) appears after the time—as for the third operation, which is fitting in department 52 (the small-parts department)—and may only be used once on any particular operation. The next time, the standard time may be raised but must bear an asterisk. The routing department keeps a file of all types of operations and uses them for setting standard times. We see also that this order was not routed until the tenth, which may have been the reason for delay in the delivery of the pattern to the foundry, although casting tickets are usually printed before machine-shop scheduling. It should be noted that all work in the machine department must be scheduled on order Y-1509 between June 25 and July 17, which happen to be the dates on which the order should leave the foundry and the machine shop. This order sheet, with the notes of the time setter on the margin, is sent to the duplicating room that produces the actual work tickets. It also makes the foundry tickets that have no detailed scheduling for each operation and involve no time standards. A clerk will now type all this information for item 1-8 on a standard form in "ditto" ink, and various machine-shop work tickets will be run off on a "ditto" machine. The first card produced will be the machine-shop master card that is reproduced in

| Deliver to 52 | Charge to 52 | Date of order 5/16/40 | Production order No. Y-1509 |
|---|---|---|---|
| % Customer So. Porto Rico Sugar Co. Trading Corp. For Santa Fe Mill | | Due dates To be completed by | |
| | | 14 6/5 | Sheet No. 1 |
| Machine No. General drawing | | 22 6/10 | |
| Description 16″ side-roll box crown wheels and couplings for 32″ × 66″ mill | | 20 6/25 | Sheets |
| This list is for one, make One on this order | | M 7/17 | Ship with |
| | | Date of required shipment 7/22 | |

June 10, 1940

| Item | Ordered from dept. | Make | Mat. | Patt. | Drawing | List of parts | Weight | Cost |
|---|---|---|---|---|---|---|---|---|
| 1 | OP | 2 | 35M | RF-$^{14}/_{128}$ | 192-485 | Side-roll boxes | | |
| 2 | | | | | | | | |
| 3 | 12 | 16 | MI | | 192-485 | 1″ pipe plugs for do. | $22^6/_{10}$–$20^6/_{25}$ | (5051) pr. for plugs $^6/_{26}$ S.T.T.<br>52 Plug & Test $^6/_{27}$ $2^{\circ}$E |
| 4 | | | Boxes machined ready for 16″ journal liners (no liners furnished) | | | | | (4635) PL $^7/_8$ $10^{\circ *}$ |
| 5 | | | | | | | | (4732) H Bo Fa for liner $^7/_9$–$10^{\circ *}$ |
| 6 | | | | | | | | no liner furnished |
| 7 | | | | | | | | (451) Lo pr. $^7/_{10}$ .5E |
| 8 | OP | 3 | 45C | 2926 | 193-22 | $32\frac{1}{2}$″ crown wheels—18 T.—5.672″ P.—$14\frac{1}{2}$″ face—bore 17.508″ | $22^6/_{10}$–$20^6/_{25}$<br>(4751) OBT $^7/_8$ $22^{5*}$ | (5051) pr. comp. $^7/_{11}$ S.T.T. |
| 9 | | | | | | | (4713)K$^3$ $^7/_{10}$ $8^{7*}$ | Total pr. time $6^{\circ *}$ |
| 10 | | | | | | Two straight featherways $2\frac{3}{8}$″ × $\frac{3}{4}$″ at 90° | 52 Fit $4^5$ E | 52 paint $^7/_{17}$ .$^5$E |
| 11 | | | | | | | | 52 ship $^7/_{22}$ .$^5$E |
| 12 | | | | | | | | 52 chip check $^7/_8$ $3^{\circ}$E |
| 13 | OP | 2 | 25C | RF-$^1/_{30}$ | 192-14 | Couplings—$12^{11}/_{16}$″ square for $12\frac{1}{2}$″ square shaft | $22^6/_{10}$–$20^6/_{25}$ | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 16 | | Pack for export | | | | | | |
| 17 | | | | | | | | |
| 18 | NOTE: | The above boxes are for changing over the roll journals from 15″ and 14″ dia. to 16″ per layout PS-966 and replace old boxes on 192-109 housing 192-108. Rolls in future are to be furnished to 201-350. | | | | | | |
| 19 | | | | | | | | |
| 20 | | | | | | | | |
| 21 | | | | | | | | |
| 22 | | | The first shafts are on order W-4372. | | | | | |
| 23 | | | The first change-over step made on order W-4373. | | | | | |
| 24 | | | | | | | | |
| 25 | | | | | | | | |
| 26 | | | | | | | | |
| 27 | | | | | | | | |
| 28 | | | | | | | | |
| 29 | | | | | | | | |
| 30 | | | | | | | | |
| 31 | | | | | | | | |

FIG. 75.

| ORDER NO. | ITEM NO. | PIECE | F. 399A | MAT'L. | PATT. NO. |
|---|---|---|---|---|---|
| Y-1509 | 108 | 32-1/2" Crownwheels, 18T, 5.672"P, 14-1/2"Face, Bore 17.508" | | 45C | 2926 |

| DWG. NO. | NO. PCS. | |
|---|---|---|
| 193-22 | 3 | PRODUCTION & COST RECORD |

| MATERIAL DATES ORDERED | MATERIAL DATES RECEIVED | TOTAL HRS | TOTAL COST |
|---|---|---|---|
| | | | |

| NO. PCS. | MATERIAL | WEIGHT | COST | M. S. OPERATIONS HOURS | M. S. OPERATIONS COST | OPERATION | SCHEDULE DATE | STANDARD TIME | MAN NO. | MACH. NO. | DATE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 22 | 6/10 | | | | |
| | | | | | | 20 | 6/25 | | | | |
| | | | | | | 1-4751VBT | | | | | |
| | | | | | | | 7/8 | 22.5* | | | |
| | | | | | | 2-4713Ks | | | | | |
| | | | | | | | 7/10 | 8.7* | | | |
| | | | | | | 3-52Fit | | 4.5E | | | |
| | TOTAL | | | | | | | | | | |

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

Y-1509 108 32-1/2" Crownwheels 18T 45C 2926

| ORDER NO. | ORDERED | ITEM NO. |
|---|---|---|
| | | |

ORD. DEPT. REQ. DATE

STOCK DIV. REQ. DATE

PIECE

| PATT. DEL'Y | FDRY CAST DATE | FDRY CAST NO. PCS. | RECEIVED DATE | RECEIVED NO PCS |
|---|---|---|---|---|
| | | | | |

REPLACE R-

DATE

CHARGE

PROMISES

WANTED

PUR. ORD. NO.

ORDERED OF

FIG. 76.

Fig. 76. There will also be three other cards for the other three items that complete this order, Y-1509. These master cards are sent to the machine-shop control office and filed first according to shop-order number and next by item number in visible files, which leaves the bottom of each card visible showing the line of information printed along the bottom of each master card. This helps readily to identify each card in the file. Work cards are next run off for each of the machine operations. There will be three for item 1-8. To save typing, the same master-card form is used, and an arrow on each work ticket shows for which operation a particular ticket is intended. Figure 77 reproduces these three work tickets for the three scheduled

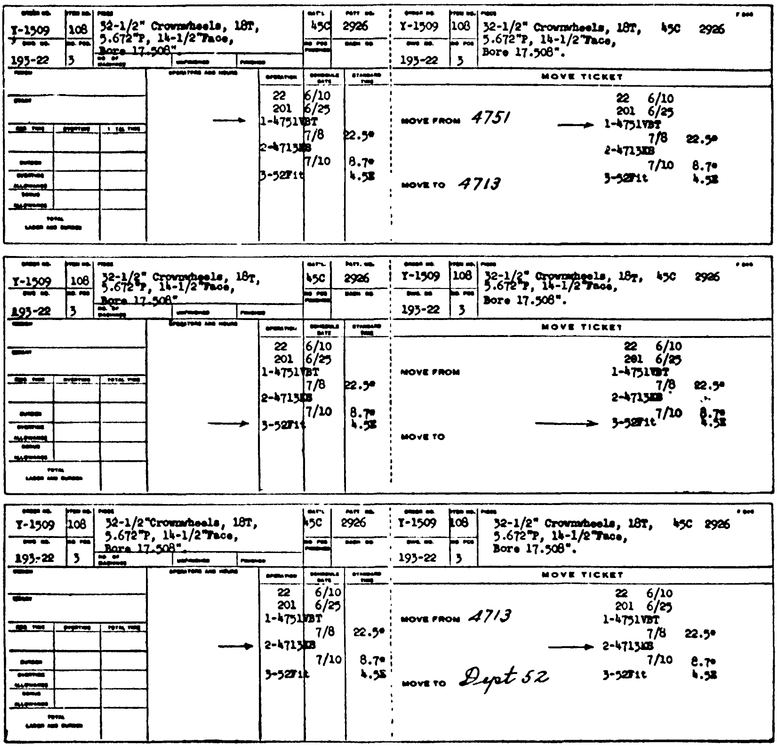



FIG. 77.

operations in the machining of item 1-8 and shows the cards as they are sent to the machine-shop control office. The routing sheet is then sent back to the time setters, who file the sheet away in loose-leaf binders for reference. When the work tickets are received in the control office, they are put in the "dead file," which contains all the work tickets for material that has not been received in the machine department. These tickets are filed by shop-order number and item number and remain there until the material is received. Machine-shop work tickets are on colored cards. Replaces, breakdowns, and stock orders appear on colored tickets (green, red-striped, and white) similar to those used in the foundry. All regular work, however, appears upon salmon-colored tickets, irrespective of the material involved.

With the master cards in place in the visible file and the work tickets in the dead file, the work of the machine-shop control office begins with the posting of data from the pattern-delivery sheets (Fig. 67), the report of castings made (Fig. 70), and the interdepartmental shipping memorandum (Fig. 71) to the proper spaces on the right-hand side of the master card, which is used to keep track of delivery of material. These entries can be seen for item 1-8 on the completely filled-in master card in Fig. 81. They are a duplication of records that were kept by the foundry control office. When the report of the arrival of the three castings for the crown wheels was received in the machine-shop control office, the final posting on the right-hand stub of the master cards for item 1-8 was made, and the file-clerk knew that this item was ready for machine-shop work. If this item had been purchased, its delivery would be made known to the control office on either of the forms reproduced in Fig. 72. He would then go to the dead file and take out all the work tickets for item

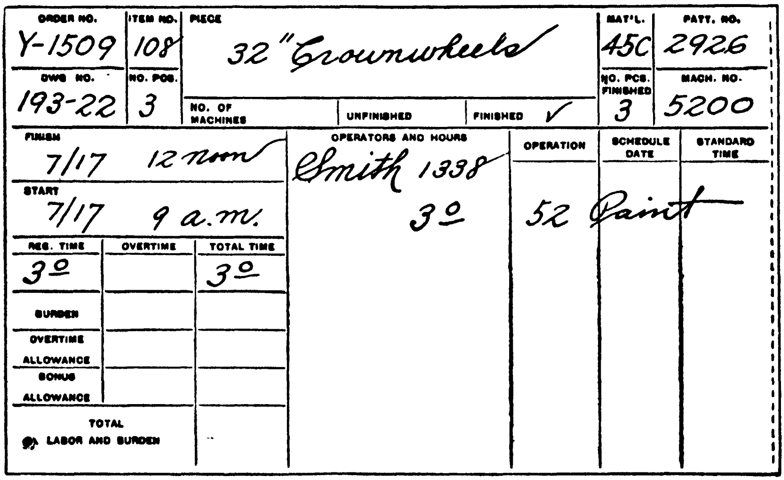
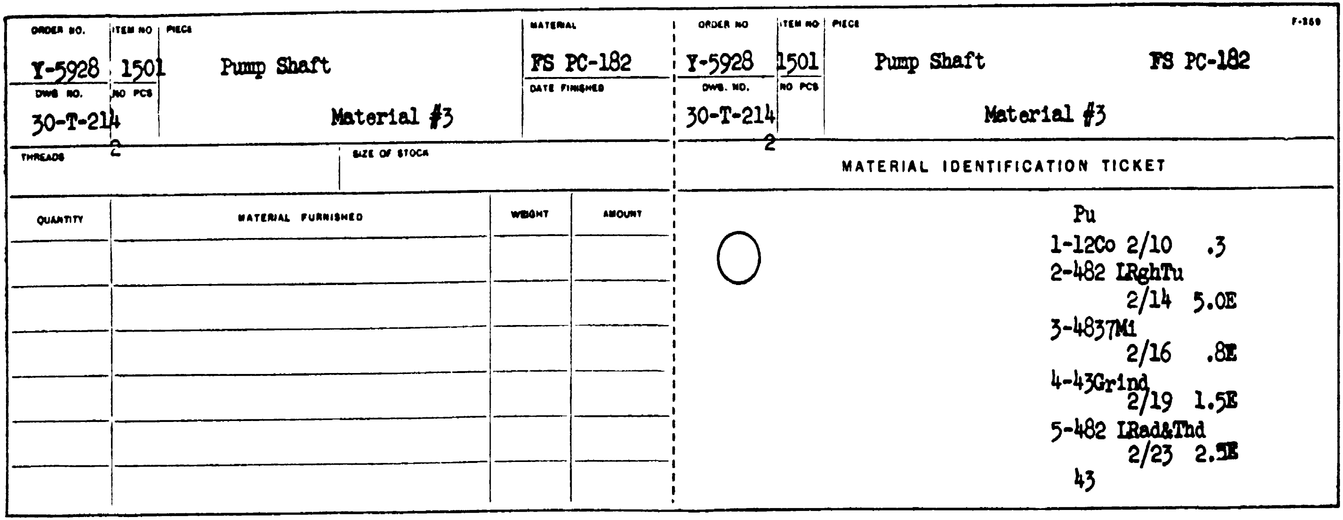

ORDER NO. Y-1509
ITEM NO. 108
PIECE 32" Crownwheels
MAT'L. 45C
PATT. NO. 2926
DWG NO. 193-22
NO. POS. 3
NO. OF MACHINES
UNFINISHED
FINISHED ✓
NO. PCS. FINISHED 3
MACH. NO. 5200
FINISH 7/17 12 noon
START 7/17 9 a.m.
OPERATORS AND HOURS Smith 1338 3.0
OPERATION 52 Paint
SCHEDULE DATE
STANDARD TIME
REG. TIME 3.0
OVERTIME
TOTAL TIME 3.0
BURDEN
OVERTIME ALLOWANCE
BONUS ALLOWANCE
TOTAL LABOR AND BURDEN

FIG. 78.

1-8 (three), and the ticket for the first operation would be put in the "work-ready" rack opposite machine 4751, thus indicating that the VBT operation on these crown wheels can now be performed. This rack has three visible compartments for each of the machine tools in the shop. Our VBT ticket will first be put in the "second" slot. The remaining tickets on any job are filed in the "work-not-ready" rack by schedule dates and type of machine tool. There is a separate compartment for each day of the next three months for each type of machine. For example, our second work ticket will be placed under "keyway cutters" in the compartment allocated for all other jobs on the keyway cutters for July 10.

When machine 4751 becomes available, the timekeeper will take from the compartment labeled "next," opposite machine 4751, the work ticket in that slot and tear off the left-hand (operation) side of the work ticket and give it to the operator of that machine along with the blueprint called for on the work ticket. The right-hand "move-ticket" half is placed in the "on" compartment of the "work-ready" rack opposite the machine number as an indication of the work that is on each particular machine at a given moment. The left-hand half is time-stamped with the



ORDER NO. Y-5928 | ITEM NO 1501 | PIECE Pump Shaft | MATERIAL FS PC-182
DWG NO. 30-T-214 | NO PCS 2 | Material #3 | DATE FINISHED
THREADS | SIZE OF STOCK

| QUANTITY | MATERIAL FURNISHED | WEIGHT | AMOUNT |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

ORDER NO Y-5928 | ITEM NO 1501 | PIECE Pump Shaft FS PC-182 | F-269
DWG. NO. 30-T-214 | NO PCS 2 | Material #3

MATERIAL IDENTIFICATION TICKET

Pu
1-12Co 2/10 .3
2-482 LRghTu
2/14 5.0E
3-4837Mi
2/16 .8E
4-43Grind
2/19 1.5E
5-482 LRad&Thd
2/23 2.5E
43

FIG. 79.

beginning and finishing times, and the operator's number and time are entered just as they were in the foundry. In the meantime, the dispatcher on the board looks through the tickets that are in the "second" compartment for machine 4751 and puts the ticket into the "next" compartment that has the oldest schedule date. In this way orders that have been held up tend to get preference, as do red-striped breakdown jobs and green replaces. During a war emergency, priority jobs are given preference over even breakdown jobs. Priority ratings are stamped on the face of the ticket so that the dispatcher will see it readily and give it right of way. Thus, when the VBT ticket for item 1-8 becomes the oldest scheduled job in the "second" slot opposite machine 4751, with no breakdown, replaces, or priority orders ahead of it, the work ticket that we are following moves to the "next" compartment. When next the machine is idle, the left-hand half goes to the operator of machine

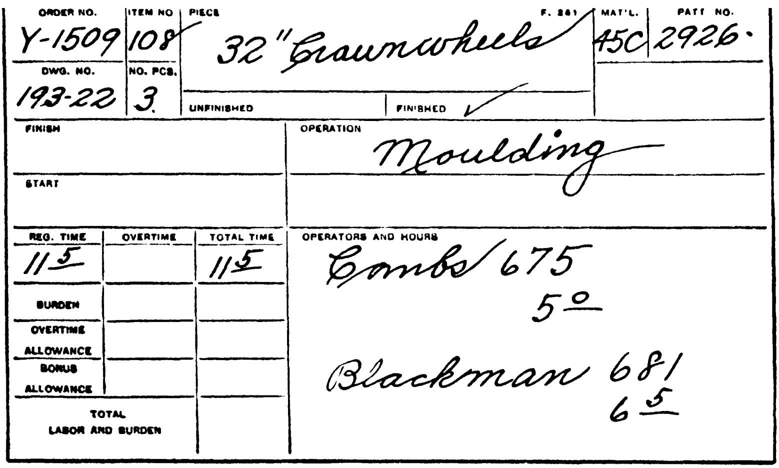

ORDER NO. Y-1509
ITEM NO 108
PIECE 32" Crownwheels
F. 241
MAT'L. 45C
PATT NO. 2926
DWG. NO. 193-22
NO. PCS. 3
UNFINISHED
FINISHED ✓
FINISH
START
OPERATION Moulding
REG. TIME 11 5
OVERTIME
TOTAL TIME 11 5
BURDEN
OVERTIME ALLOWANCE
BONUS ALLOWANCE
TOTAL LABOR AND BURDEN
OPERATORS AND HOURS Combs 675 5 0 Blackman 681 6 5

FIG. 80.

4751 and the move half to the "on" compartment. When the operation is completed, the work half goes to the cost office, with the timekeeper's entries on it, and the move half is taken from the "on" slot and given to an inspector who retains the ticket until the work passes his inspection. He then either puts the ticket on the work as an indication that the work is ready to be moved to the next operation or gives the ticket directly to a factory move man. When the move man delivers the crown wheels to the next machine scheduled (4713), the operator of that machine signs the move ticket as a receipt of the material, and the move man returns the ticket to the control office, where it serves as an indication that the item is ready for the next operation. The dispatcher will then pull the KS ticket from the "work-not-ready" rack, and the whole process will be repeated when the ticket is placed in the "second" slot opposite machine 4713. This is repeated until all the tickets are used and work moves to the shipping department, erecting shop, or, as in this case, the small-parts department (52). Here it was necessary to paint the parts, and a special work ticket was written out, as shown in Fig. 78. It will be noted that Fig. 78 shows that the painting has been completed and the time recorded.

Yellow machine-shop tickets are specialized "cutoff" tickets that are used when pieces of material are to be cut from bar stock from the stock room. Although

| ORDER NO. | ITEM NO. | PIECE | F. 399A | MAT'L. | PATT. NO. |
|---|---|---|---|---|---|
| Y-1509 | 108 | 32-1/2" Crownwheels 18T<br>5.672"P 14-1/2" Face<br>~~Bore 17.508"~~ | | 45C | 2926 |
| DWG. NO. | NO. PCS. | PRODUCTION & COST RECORD | | MATERIAL DATES ORDERED | RECEIVED |
| 193-22 | 3 | | | | |

| TOTAL HRS | TOTAL COST |
|---|---|
| | |

| NO. PCS. | MATERIAL | WEIGHT | COST | M. S. OPERATIONS HOURS | M. S. OPERATIONS COST | OPERATION | SCHEDULE DATE | STANDARD TIME | MAN NO. | MACH. NO. | DATE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cement | | | | | 22 | 6/10 | | | | |
| | Process | | | | | 20 | 6/25 | | | | |
| | | | | | | 1-4751VBT | | | | | |
| 3 | | 6650 | | 19 9 | | | 7/8 | 22.5* | 1216 | 4751 | 7/12 |
| | | | | | | 2-4713KS | | | | | |
| | | | | 4 8 | | | 7/10 | 8.7* | 1224 | 4713 | 7/16 |
| | | | | 4 5 | | 3-52Fit | | 4.5E | 1337 | 5200 | 7/15 |
| | | | | 3 0 | | 4-52 Fit | | | 1338 | 5200 | 7/17 |
| | TOTAL | | | | | | | | | | |

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

Y-1509 108 Crownwheels 45C 2926

| ORDER NO. | ORDERED | ITEM NO. |
|---|---|---|
| | | |

ORD. DEPT. REQ. DATE | STOCK DIV. REQ. DATE

PIECE

| PATT. DEL'Y | FDRY CAST DATE | FDRY CAST NO. PCS. | RECEIVED DATE | RECEIVED NO PCS |
|---|---|---|---|---|
| 6/11 | 6/19 | 3 | 6/24 | 3 |

REPLACE R- DATE

CHARGE

PROMISES

WANTED

PUR. ORD. NO. | ORDERED OF

FIG. 81.

Y-1509 calls for no such material, an example of such a ticket on another order appears in Fig. 79. The top sections of each ticket are similar to a regular work ticket, except that there is room for information as to threading and also to designate the size of stock that this item shall be cut from. The left-hand work section of the ticket is retained by the cutoff department, and the right-hand section serves as an identification of the material and as a signal to the move men to move the material to the next operation, which, in this case, is on machine 482. The rest of the work tickets for this item are the regular salmon color, and the routine is the same as followed through for item 1-8.

The only remaining work ticket is the helper's gray ticket, which is used only in the blacksmith shop and foundry and serves only as a time-record card for the cost department. It is of no concern to the production-control department and is not printed by the routing department with the other cards but is handwritten by the timekeepers as the need arises. A helper card is reproduced in Fig. 80.

At the completion of each job, all machine-shop time tickets are collected by the cost office. Various information is posted to the master card, which has been taken out of the visible file in the machine-shop control office after the completion of the machine work. Foundry costs will be transcribed from the foundry cost card in Fig. 69. The master card for item 1-8 on Y-1509 is shown in Fig. 81, and on it are seen the completed time entries. Later the cost department will figure the cost of this job, and the card will be saved as a permanent record of the production and cost of item 1-8 on Y-1509. From this card it can be seen that men 1216 and 1224 were able to perform their operations in less than the standard time allowed, that the fitting operation was estimated about right, and that the first two operations were late. However, the item left department 52 on the seventeenth, which was the date scheduled on the shop-order sheet (Fig. 61).

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# INDEX

## G



## H



## I



## J



## L



## M